Electronic Engineering

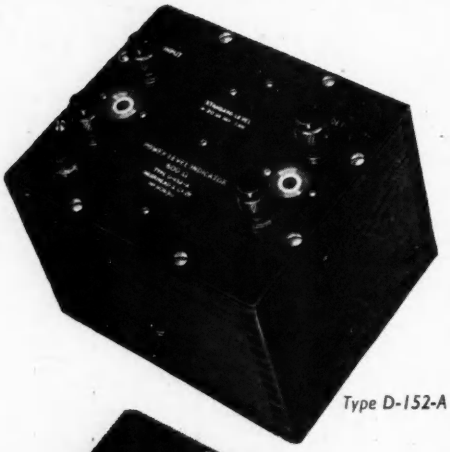
INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

The Betatron
The Cathode-coupled Double Triode Stage
The Etherscope
The Comparative Strengths of Porcelain and other Insulators
L.F. Transformer Stampings — Design

2/- MAY, 1944

POWER LEVEL INDICATORS



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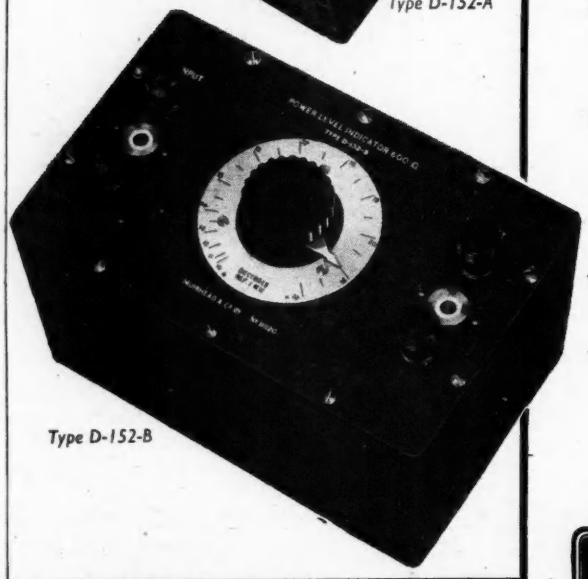

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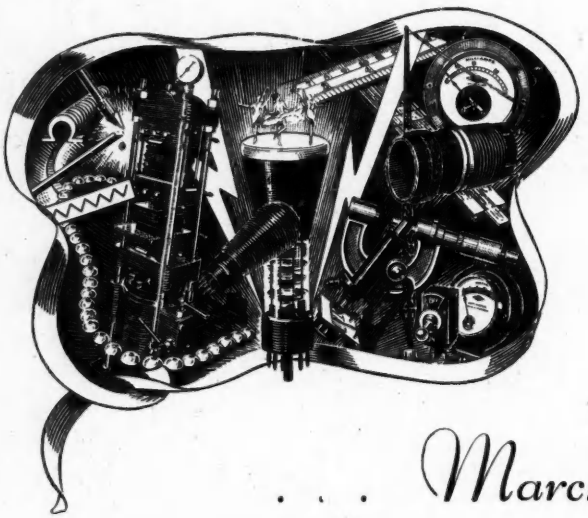

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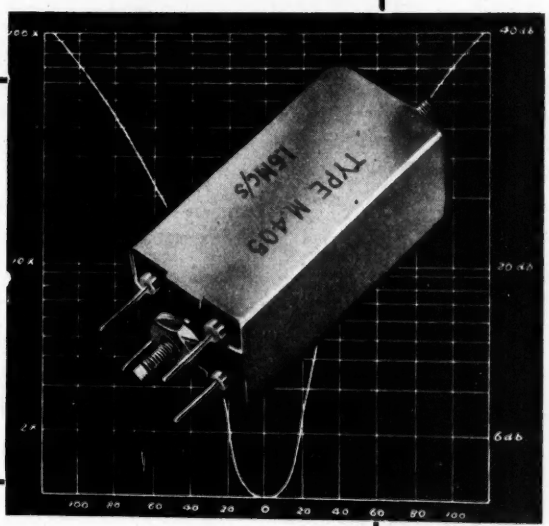

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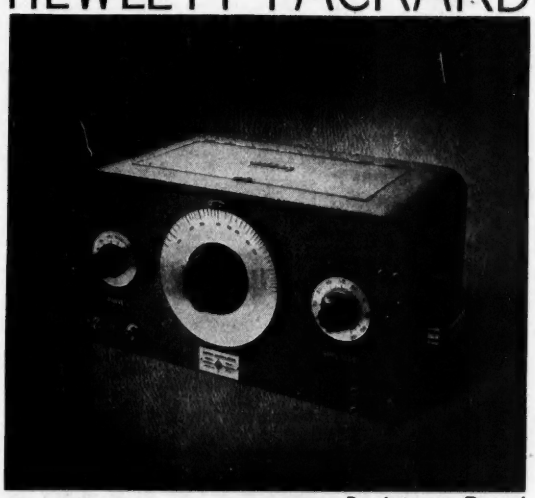

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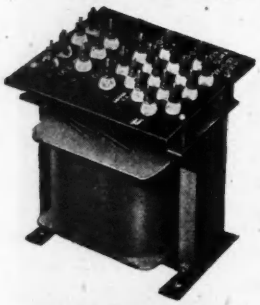

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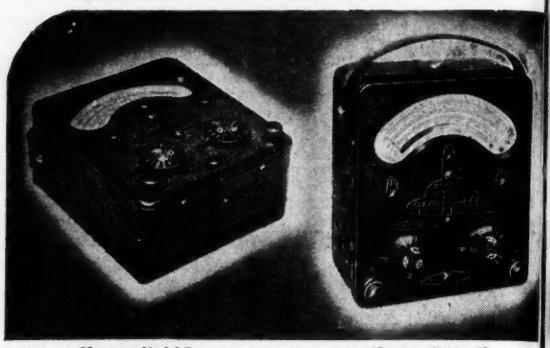

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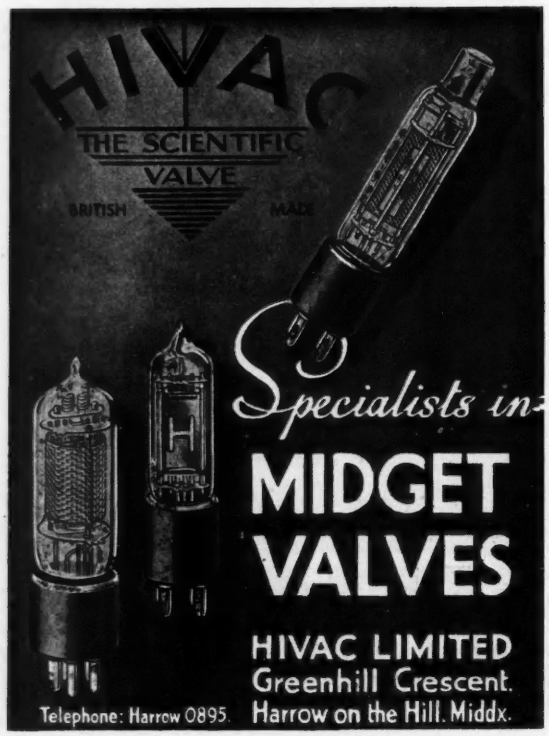

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Electronic Engineering

MAY, 1944

Volume XVI. **No. 195.**

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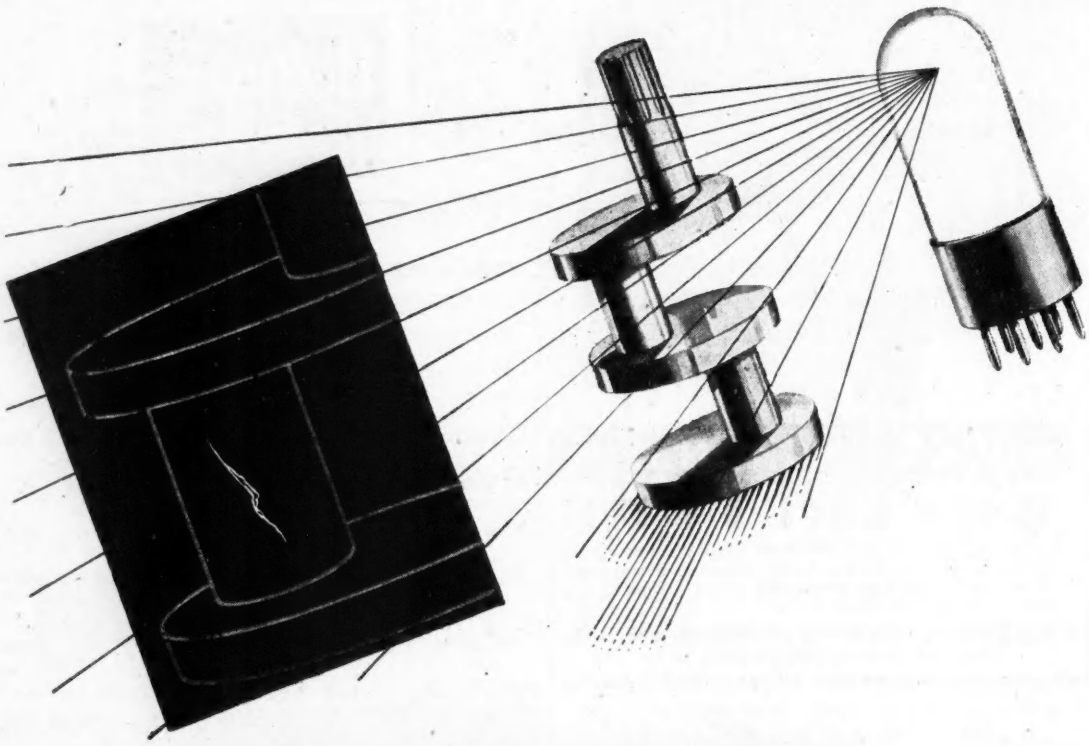

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Notice Board

Completion of Volume

THIS issue completes Volume XVI of this Journal—from June 1943 to May 1944. The odd period is accounted for by the date on which the journal changed its name, and it is hoped to be able to sort things out after the war and make the volume line up with the year.

A standard binding cover is not yet available but " self-binders " can be obtained from the Circulation Department, price 3s. 6d., post free. These hold 24 copies, which are slipped through strings in the spine to keep them in place.

Binding covers for *Electronics, Television & Short Wave World*, as this journal was formerly known, can still be obtained, price 2s. 3d., post free.

Applications for both self-binders and binding covers should be accompanied by a postal order. The publishers regret that they cannot undertake orders for binding complete volumes.

Back Copies

Nearly all the stock of copies of *Electronic Engineering* is exhausted within a few days of issue.

Readers who send in for back copies are asked to enquire first whether they are available and thus save time and trouble in returning the money sent to the Circulation Dept.

Owing to the steady demand for back copies, any readers having them for disposal are asked to write to the Circulation Dept., giving particulars of month and year.

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The number of copies of this journal printed each month is strictly limited by the paper restrictions.

There are many readers who see copies occasionally, but cannot obtain them regularly on account of shortage of supplies.

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Note to regular readers :

If there is any difficulty in obtaining your copy regularly, let us know, giving your newsagent's name and address.

Data Sheets

The Data Sheet series, which has been a feature of this journal for the past three years is being temporarily discontinued. Its place will be taken for the remainder of the year by a useful series of sheets illustrating cathode-ray tube technique, specially arranged by Dr. H. Moss.

Readers who have missed the earlier numbers in the Data Sheet series will be pleased to know that the publishers are arranging to issue them in book form as soon as possible.

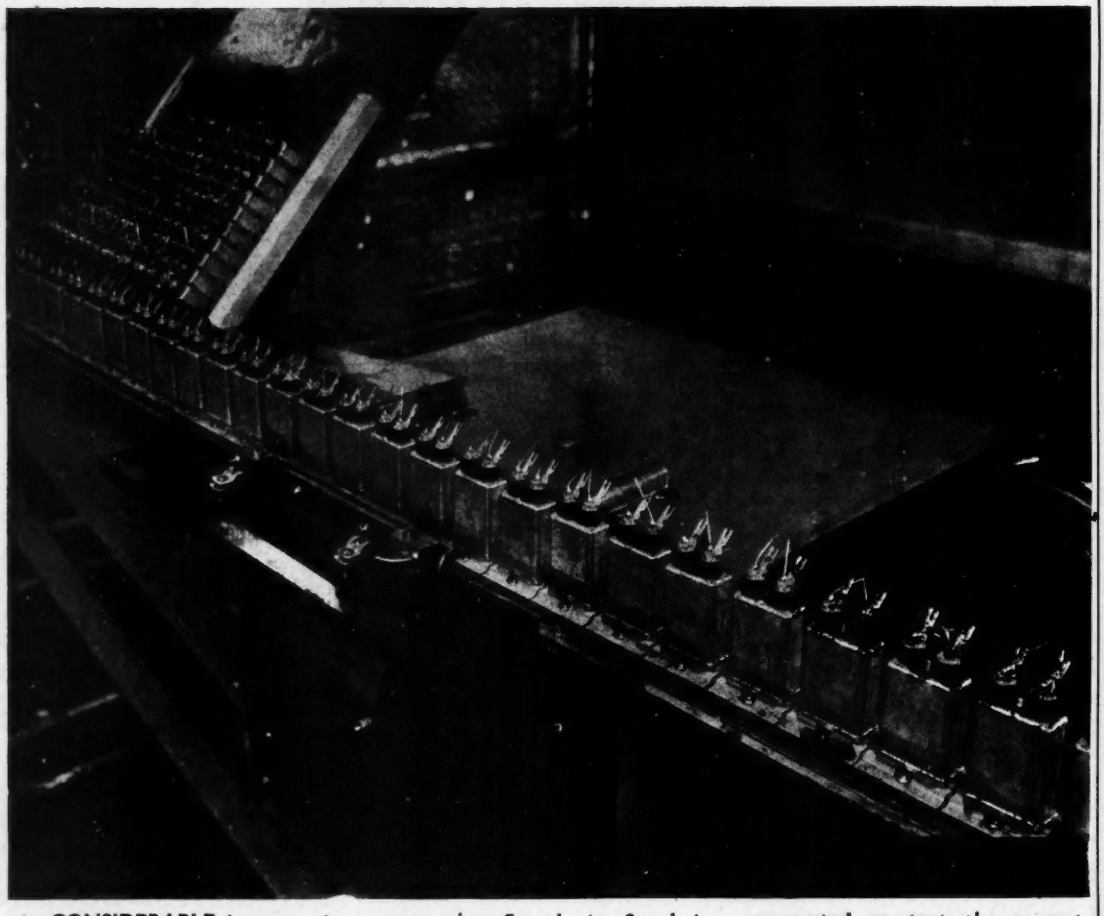
Electronic Engineering Monographs

" Frequency Modulation " is temporarily out of print. The author is preparing a Second Edition which will be issued at an early date.

" Plastics in Radio " is also being reprinted and stocks will be available by the time this notice appears.

The third Monograph in the series will be " Gas-filled Relays and their Application," by G. Windred, A.M.I.E.E., and a further announcement will be made when the booklet is ready for publication.

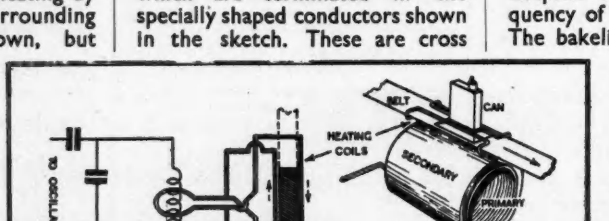
Soldering with High Frequency



A CONSIDERABLE increase in production rate has been achieved by the use of high frequency for soldering the bottoms of condenser cans in the R.C.A. plant. The method of heating by means of an h.f. coil surrounding the part is well known, but a recent improvement enables the cans to be passed through the h.f. field continuously on a conveyor belt as shown in the photograph.

A ring of solder is laid on the bottom plate, which is previously fluxed, and the top part, also fluxed, is fitted in position before passing to the conveyor. The assembly is then passed through a single turn secondary winding, the ends of which are terminated in the specially shaped conductors shown in the sketch. These are cross connected so tnat the current flows in opposite directions on each side of the can. The primary winding is connected in the tank circuit of a 4 kW. Colpitts oscillator, having a frequency of 400 kc/s.

The bakelite block on which the cans are fitted acts as a centring jig and ensures that the heat is accurately localised. The present rate of soldering is 2,500 per hour, but it is expected to reach 4,000 an hour with further development.



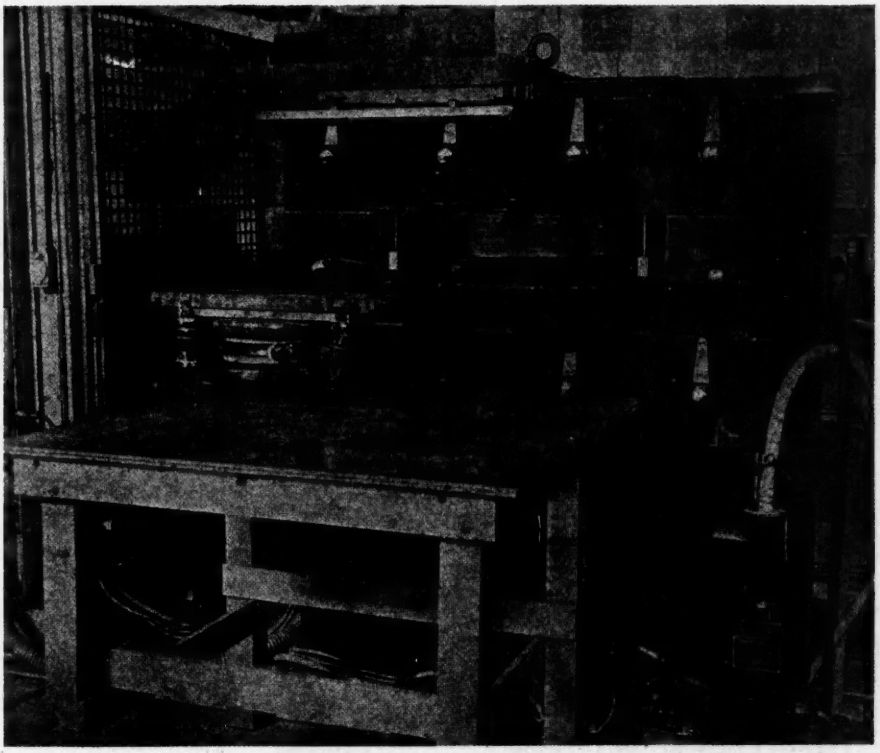


Fig. 1. The old Betatron, on the table (2.3 MV.), compared with the new (20 MV.).

The Betatron

By D. W. KERST*

An electron induction accelerator, designed to give the most penetrating and energetic electrons and X-rays ever produced. This important account, by the inventor, is reproduced from "Radio News" Magazine by permission of the publishers.

WHILE experimenters in nuclear physics in the last decade had energies extending up to 16 million electron volts available in the form of high-speed positive ions from the cyclotron, accelerators giving such high energy to electron beams were not available. Much of our information about the behaviour of high-speed electrons had to be obtained from experiments with radio-active substances which give off high energy B-rays and from the feeble cosmic radiation which contains many energetic electrons. The cyclotron which produced the high-energy positive ions could not handle electrons of similar energy, and the main accelerator of electrons was the Van de Graaff electrostatic generator which operated up to 4.5 million volts.

The reason that the cyclotron did not provide high-energy electrons as well as positive ions lies in the fact that the lightweight electron behaves relativistically when its kinetic energy is still very small. When the kinetic energy of a particle approaches or exceeds the energy of its rest mass, mc^2 pronounced relativistic effects occur. For example, the rest mass of a proton is nearly equivalent to one billion electron volts. A proton having approximately this kinetic energy would behave in a relativistic manner. However, an electron has a rest mass equivalent to only one-half a million electron volts and will be travelling at approximately nine-tenths of its upper speed limit, the velocity of light, if it has this amount of kinetic energy. Since one of the requirements for operation of the cyclotron is that the speed of the accelerated particle increase while it is being accelerated, it is impossible for an electron, already close to its speed limit, to fulfil this condition, and thus the cyclotron could be used only for producing electrons with energy below 500,000 volts.

The operation of the betatron is independent of whether the particles behave in a classical or relativistic manner. In fact the electrons commence their acceleration in the classical region with a speed of approximately one-fourth the velocity of light and eventually attain a speed within 0.03 per cent. of the velocity of light. With the original operation of the betatron it became evident that this device could be used for imparting practically any desired energy to electrons, and at once plans were made for a 100-million volt accelerator for pure physical research at the university. It was realised that with this much energy it might be possible to materialise mesons, the heavy elec-

* Professor of Physics, University of Illinois.

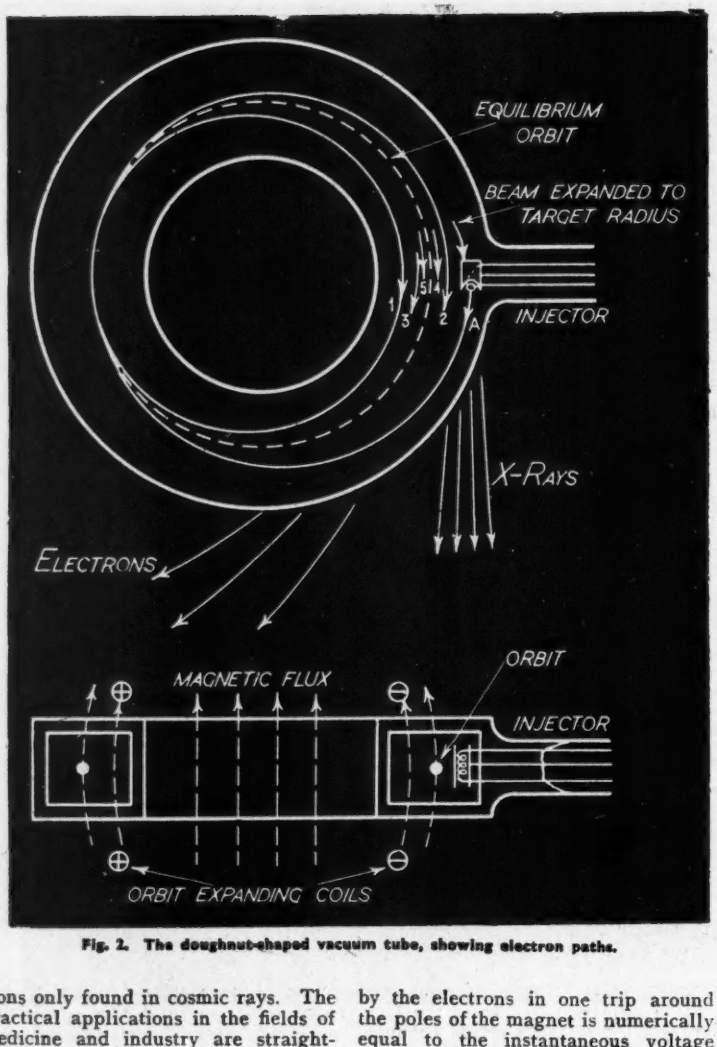
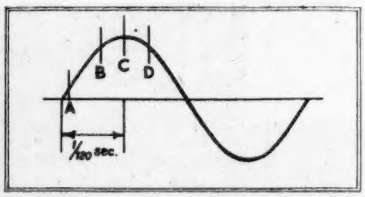


Fig. 2. The doughnut-shaped vacuum tube, showing electron paths.

trons only found in cosmic rays. The practical applications in the fields of medicine and industry are straightforward and to-day require much lower energies.

The betatron looks in some respects like a miniature cyclotron, since it is an electromagnet; but it operates with an alternating instead of a unidirectional magnetic field. Unlike the cyclotron, the betatron accelerates charged particles in one continued "push," rather than with repeated "kicks."

It is the increasing magnetic flux linkage within the electron orbit produced by the alternating current magnet which provides the electromotive force to steadily push the electrons around this flux. By providing that the electrons travel in the gap between the poles of the electromagnet their paths are bent into circular orbits, and the energy gained by the electrons in one trip around the poles of the magnet is numerically equal to the instantaneous voltage which would be read on a voltmeter connected to one loop of wire placed at the electron orbit. Since the electron is travelling approximately with the speed of light, it travels many times around the pole of the magnet while the alternating flux builds up from zero to its peak value. With each revolution the electron gains an additional amount of energy, and the final equivalent voltage of the electron is approximately equal to the voltage induced on a secondary coil placed at the orbit, having a number of turns equal to the number of electron revolutions. The betatron thus applies the transformer action directly to the electron instead of applying it first to a secondary coil connected to a high voltage vacuum tube which in turn applies the voltage



The magnetic cycle : A is the time of injection of electrons, B the time at which the orbit is expanded to cause them to strike the target.

to the electron stream. Thus the electrons receive their enormous energy without the production of a high potential and without the difficulties associated with high potential vacuum tubes.

In the original betatron, which was only about 19 inches long and 10 inches high, the electrons reached an energy of 2.3 million electron volts and travelled a distance of approximately 80 miles, gaining a peak of about 20 volts per revolution.

It is necessary that this great length of electron path be travelled in a high vacuum tube. The betatron tube containing the orbits is a doughnut-shaped, highly evacuated vessel which is placed between the poles of the magnet as illustrated in Fig. 1.

Operation of the Betatron

Electrons from an electron gun called the injector are shot tangentially into the doughnut at the time in the cycle when the magnetic field is small. As these electrons circulate between the poles of the magnet, the magnetic field is increased. They gain energy at every revolution and finally strike the back of the injector which acts as a target for the production of X-rays or for scattering the electrons out through the walls of the tube. Figure 2 shows the circular vacuum tube in which injected electrons circulate. The electrons must be directed against the target when the magnetic field has reached its peak value, for at this time the electron energy is at a maximum. A period of three-fourths of a cycle then elapses before electrons are again injected at a time corresponding to A on the H curve of Fig. 2. To spiral the electrons out toward the target an excess of magnetic flux is forced through the centre of the electron orbit at the time indicated by B.

Since approximately 100,000 revolutions are described by an electron in one quarter of the alternating current cycle, the electrons must not spiral inwardly or outwardly during the main part of their acceleration period. A stable orbit, called the equilibrium orbit, is created at a fixed

radius by carefully adjusting the proportions of the magnetic pole faces. The distribution of flux which must exist between the poles, if the electrons travel in this fixed circle, can be understood from the following analysis.

The voltage gained by the electron per centimetre of path depends upon the rate of change of flux linkage, that is,

$$dE/dx = (e/2\pi rc)d\phi/dt$$

is the energy gained per centimetre or the force in dynes acting upon the electron to accelerate it. ϕ is the magnetic flux linkage with the orbit of radius of r centimetres. e is the electron charge in e.s.u., and c is the velocity of light. This force, by Newton's second law of motion, must equal the time rate of change of momentum, $d(mv)/dt$. The momentum of an electron travelling in a circle in a magnetic field is $mv = (e/c)Hr$, since the centripetal force must be equal to the magnetic force. Differentiating this, we get

$$d(mv)/dt = (er/c)dH/dt),$$

which can be equated to the accelerating force of the electron,

$$(e/2\pi rc)d\phi/dt.$$

Integration shows that $\phi = 2\pi r^2 H$. This requirement must be fulfilled by the flux linkage and the magnetic field at the orbit if the electron is travelling in an orbit of fixed radius, r. In an air gap magnet ϕ is always proportional to H so that if this relation holds at one time in the magnetic cycle it will hold at all times, provided that no portion of the flux path saturates. Fig. 3 shows the type of magnetic poles used in the betatron. The excess iron in the centre of the poles provides the flux necessary to hold the equilibrium orbit at a fixed radius. Without this excess iron the electrons would spiral inwardly continuously.

It is not sufficient that the flux relation alone be satisfied since this does not insure that stray electrons will be focused into the equilibrium orbit. The complete theory of focusing includes the influence of the shape of the magnetic field on the electron orbits as well as the influence of the rapidly rising magnetic field. It was this theory which was worked out at the University of Illinois[1] that made possible the design of a satisfactory betatron, although previous investigators had no definite success. If the electrons did not travel such enormous distances in the acceleration chamber, the field might not need such excellent focusing properties.

By properly arranging the pole faces, the electrons can be caused to oscillate axially or radially about the equilibrium orbit. The curvature of the lines of force (Fig. 3) provides a radial component of the magnetic field oppositely directed above and below the orbit. This slight radial field is in such a direction that it always forces a displaced electron back toward the orbit, thus acting as a restoring force which causes the electron to oscillate across the orbit.

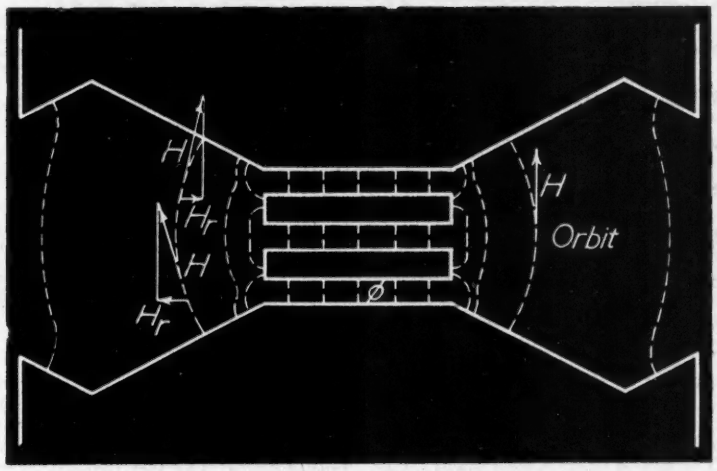


Fig. 3. Curvature of lines of force between the poles of the betatron. There is a radial component to the field everywhere except in the central plane, and this component always forces electrons back to the plane.

The angle of the pole faces is made so that the magnetic field falls off in a radial direction less rapidly than centripetal force, mv^2/r, a hyperbola. Then the magnetic force, F_m, in Fig. 4 will be less than the centripetal force, F_c, which is necessary to hold the electron in, when the electron is at a radius less than r_0; and the magnetic force is greater than the requied centripetal force at radii larger than r_0 (at a radius r). Thus the stray electron within the equilibrium orbit finds itself held by a magnetic force insufficient to keep it at this small radius, and while rotating about the orbit it also moves outward and crosses the equilibrium orbit. When it is outside of the equilibrium orbit, the magnetic force is greater than that necessary to hold it in an outside circle, and hence the electron again moves back toward r_0.

These forces provided by proper shaping of the pole faces cause the axial and radial oscillations across the equilibrium orbit which are needed to bring electrons back to the orbit; but the oscillations of these electrons must be gradually diminished to form a stable beam. This decrease of amplitude, or damping of the oscillation, is provided by the transient effects of the rapidly increasing magnetic field. Since the magnetic field provides the restoring forces for axial or radial oscillation, its increase is somewhat analogous to the stiffening of a spring which is causing a mechanical system to vibrate. The amplitude of oscillation decreases as the spring becomes stiff. Likewise the straying electrons are forced by the effect of the increasing magnetic field into a compact beam which can travel many miles.

Such long electron paths can be described in rather small circles because of the ease with which electrons are affected by magnetic fields. This means that magnets of small radius can be used for very high energies. Fig. 1 shows a small 2.3 million-volt betatron (the original accelerator) and the larger 20 million-volt betatron in the laboratory at the University of Illinois. The small betatron on the table was originally run at 600 cycles per second, and the electrons gained about 25 volts per revolution at the injection time, whereas the large betatron is run at 180 cycles, and the electrons acquire a maximum of 70 volts per revolution. This magnet acts as the inductance in a resonating circuit. A large condenser bank of about 1,800 kVA capacity is used in parallel with the large betatron, and primary cables shown about the coil boxes provide the energy for the resonating circuit. The main reason for running the large accelerator at a lower frequency than the small accelerator is that the cooling problem is more easily handled. The highest possible frequency consistent with good cooling is desirable, since the

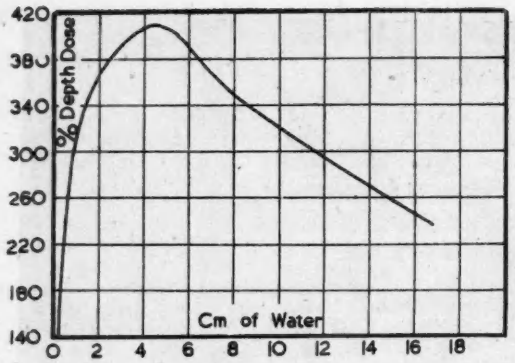


Fig. 5. Depth dose caused by 20 MV X-rays from the betatron, with the phantom at 1 metre from the target.

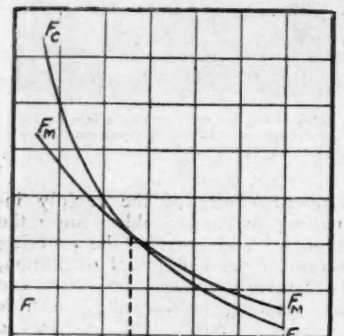


Fig. 4. F_C **is the centripetal force** (mv_2/r) **required to hold an electron at radius** r. F_m $(e/c\ H_n)$ **is the magnet force which is supplied to the electron. Radial oscillation occurs about** r_o.

more frequently electrons are put into the vacuum doughnut, the more X ray intensity will be produced.

While there may be no limit on the voltage for which a betatron can be made, there is a limit placed upon the number of electrons which can be shot into the orbit by the internal repulsion of the beam. The magnetic focusing forces can counteract the space charge forces of only a finite amount of charge when the electrons start their paths at low speed. An interesting fact is that when the speed of the electrons approaches the velocity of light, the magnetic self-focusing of the beam completely counterbalances the space charge defocusing of the beam. Magnetic self-focusing is a result of the attraction of parallel currents. This attractive force on a straying electron is equal to the magnetic field produced by the beam around itself times the product of the charge and velocity of the straying electron. If σ is the number of e.s.u. per centimetre in the beam, then the magnetic field surrounding the beam is $2\sigma v/Ac$. V is the velocity of the electrons in the beam, d A is the distance from the centre of the beam to the straying electron. Thus the force of the magnetic pull of the beam on a nearby electron moving in the same direction is $(2\sigma v/Ac)^{ev/c}$. The fact that the beam is circular is neglected, and it is imagined that for short lengths it behaves as a straight current. Then space charge repulsion on the same electron is just $(2\sigma/A)e$. Thus when v/c approaches unity the magnetic attraction for the stray electron approaches the electrostatic repulsion of this electron, and this means that space charge effects apparently disappear when the electron speed approaches the velocity of light. From the point of view of an observer riding on the electron the space charge also disappears, since he finds that his measuring stick which he uses to estimate the space charge repulsion of neighbouring electrons shrinks to a smaller proportion of the circumference of the orbit as his speed approaches the velocity of light. Thus it appears to him that the concentration of charge about him and the forces produced by it is becoming less. In the 20 million-volt betatron, the velocity of the electron approaches within 0.03 per cent. of the velocity of light, and at this speed the mass of the electron is increased to 40 times its normal size. The space charge forces after acceleration are then negligible.

Uses of the Betatron

The high energy X-rays and electrons which are made available by the betatron can be used for both physical experiments and practical purposes. With the 20 million electron volts now available probably all the elements in the periodic table can be disrupted by a photonuclear process. The heavy elements are found to require of the order of 10 million electron volts or perhaps less to disintegrate, while some of the light elements require almost the full voltage. In this photo-nuclear process the energy of the X-ray or gamma-ray is used, generally in ejecting a neutron from the parent nucleus. The exact amount of energy required for this process in different nuclei can be precisely determined by the betatron. This determination is analogous to the determination of the long wave length limit of the light used to eject electrons from the cathode of a photo-electric cell.

While the 100-million volt, 125-ton betatron which was designed for the University was to make possible certain types of cosmic-ray experiments, the practical applications of the betatron require much less energy, and consequently a convenient size of equipment. For example, electrons of 20 million volts' energy are capable of penetrating at least 10 centimetres into the human body. They could be used therapeutically in place of X-rays and they possess a great advantage over X-rays, since the ionisation produced by them would stop rather abruptly at about the middle of the body and do no damage beyond. This appears to be one of the most promising uses for the betatron, since this distribution of radiation would solve many of the radiologists' problems.

The X-rays which are produced by the betatron have intensities comparable with those produced by commercial machines. The ionisation distribution produced by these X-rays in tissue-like material is also very advantageous.[2] The usual X-ray equipment produces its maximum dose at the surface of the body, where it is not always wanted. It is desirable to localise the ionisation somewhere below the surface. Fig. 5 shows that this occurs quite naturally with 20 million volt X-rays. The maximum ionisation occurs about four centimetres beneath the surface, which makes it possible to administer a large dose to the interior of the body without damaging the surface. It is expected that the therapeutic use of X-rays from the betatron will be straightforward, since the techniques for measurement and handling X-rays are are already well known to radiologists.

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From the "Radio News," Vol. 30, No. 3, 1943.

The "Etherscope"

By D. GIFFORD HULL, Capt.*

The Etherscope is an experimental device designed to enable the signals from all stations in a given waveband to be viewed simultaneously on a cathode ray tube. The instrument is not to be confused with the Panoramic Spectroscope, which shows adjacent stations within a narrow band (± 50 kc/s.) and which is intended for checking adjacent channel conditions and the characteristics of signals generally.

Application

THE purpose of this instrument is to see at a glance how many stations there are on a given band, their relative strength, whether c.w. or modulated, when any of them close down, and when any new ones become active.

The Etherscope may be used in two different ways: firstly, for viewing active short-wave bands, commercial, broadcast or amateur; and secondly, it may be used as an automatic search on the comparatively inactive U.H.F. bands, for police, and aircraft service, etc.

As regards the short-wave bands which are comparatively "crowded," the maximum band that may be covered is limited by the size and definition of the cathode-ray tube, since adjacent channels must be distinguishable. Thus, with an average 3½-in. tube, the maximum band that may be covered is about one megacycle. At the present state of technique, it appears that the Etherscope finds its application chiefly in the U.H.F. regions. Since these bands are comparatively inactive, station separation is less important. Under these circumstances, wider bands may be viewed. Further, on inactive bands, the instrument may be used with a receiver as an automatic "search" set. For this purpose the few stations that do happen to appear on the screen, may be "rubbed out" by means of wave traps in the aerial circuit. Under these circumstances, a relay in the receiver output is inoperative. But as soon as any new stations come up, the relay will close, giving visual or aural warning to a superintendent, who will then observe the screen to ascertain the frequency of the new station. If he wants the station, he will assign an ordinary receiver to take it, and then rub it out on the Etherscope.

Mode of Operation

The underlying principle of the instrument is simple. It consists of tuning the receiver rapidly across the required band, at a predetermined repetition frequency, and synchronising the time base of an oscilloscope to this periodicy. The D.C. component of the receiver's output is then applied to the Y plates of the oscilloscope. The result will be a straight horizontal line, representing a frequency base, with several small vertical lines rising from it, each representing the presence of a radio station.

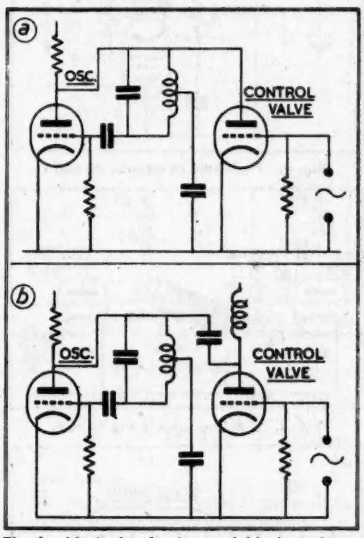

Fig. 1. Methods of using variable impedance to alter the frequency of an R.F. oscillator.

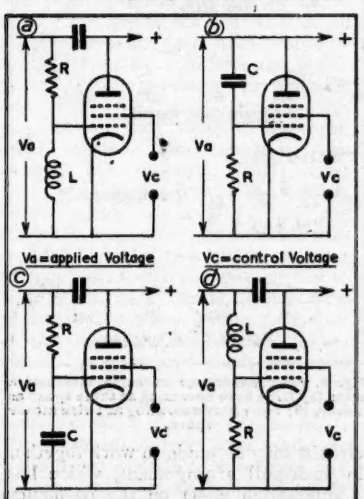

Fig. 2. Various forms of reactance valve circuit.

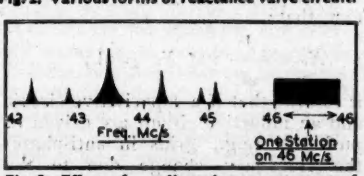

Fig. 3. Effect of non-linearity on one part of the frequency base.

The horizontal base line may be calibrated in frequency, so that the frequency of any signal may be readily ascertained. Alternatively, a calibrated oscillator may be used, its signal being also applied to the oscilloscope Y plates. The signal of the oscillator is then moved along the frequency base until it coincides with the station whose frequency is to be measured. When double beam tubes are used, several such oscillators may be used as "markers," and may be applied to the upper trace, in a downward direction.

Electronic Frequency Modulation

The periodic tuning of the receiver amounts to frequency modulation, which may be brought about by mechanical or electronic means. We will deal with some of the electronic systems which were tried during the development of the Etherscope. In all cases, the circuits discussed bring about a periodic change in local oscillator frequency.

One of the simplest circuits is shown in Fig. 1 (a). The control valve is connected across the oscillator tuned circuit. When cut-off bias is applied, the impedance of the valve is high, and does not affect the tuned circuit. As the bias is reduced, anode current flows, the impedance drops, and thus loads the tuned circuit, causing a slight change of frequency. Fig. 1(b) shows a slight elaboration of this circuit. A large condenser is placed between the tuned circuit and the control valve. When the control valve is cut off, the cold side of the condenser is virtually "in the air." But as the valve passes anode current, the impedance of the cold side of the condenser to ground decreases, and the shunting effect of the condenser on the tuned circuit becomes appreciable. This method did not give very satisfactory results, the frequency excursion was not enough, and non-linearity was present.

The Reactance Valve circuit is widely used for F.M. work. It is

* By permission of the War Office.

sometimes known as the "Inverted Miller Valve," although this inadequately expresses its action. Basically, the circuit consists of a valve with a phase-shifting network in its ground-grid-anode circuit, arranged so that the grid is ninety degrees out of phase with the anode. Under these conditions, the valve has the characteristics of a pure reactance. Depending on whether the anode current leads or lags the applied voltage, the reactance is either capacitative or inductive, and its value is readily controlled by varying the mutual conductance of the valve.. This may be done by applying bias in the form of a saw-tooth voltage, obtained from the oscilloscope, either to the grid or screen grid.

There are several ways of using the Reactance Valve, and several factors governing the choice of methods to be adopted for the Etherscope. Fig. 2 (a) and (b) show circuits that produce capacitative reactance, whilst those of 2 (c) and (d) give inductive reactance.

Analysing the action of circuit in 2 (b), the reactance of the condenser C must be large compared to the grid-ground impedance, so that the current in the condenser leads the applied voltage by ninety degrees, and hence the current in the resistor leads the applied voltage by ninety degrees. But the voltage across the resistor (grid voltage) is in phase with the current flowing in it. Thus the grid voltage leads the anode voltage by ninety degrees, and the anode current leads its voltage by ninety degrees, which is the condition existing in any capacitative circuit. The values of the elements in the network determine the phase angle, which decreases with frequency, so that in actual fact, it never reaches ninety degrees. The impedance of the anode circuit has two components—a resistive and a reactive component. Maximum modulation (or frequency excursion) is obtained when the impedance is as nearly reactive as possible. For a given frequency of applied voltage, maximum variation of reactance is obtained with a high μ valve of high internal resistance. It only then remains to use such a value of control voltage that the gain of the valve is varied through as great a range as possible, consistent with good linearity. Overloading (non-linearity) produces a distorted frequency base, as seen in Fig. 3.

Push-Pull Arrangement

The inductive and capacitative systems have already been discussed, and their circuits shown in Fig. 2. It will now be seen how two such

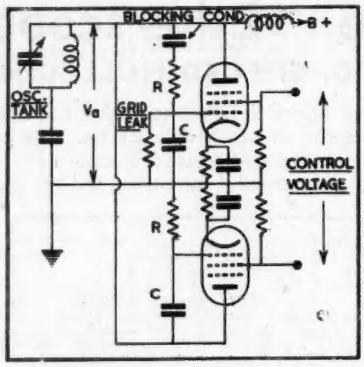

Fig. 4. Push-pull reactance circuit.

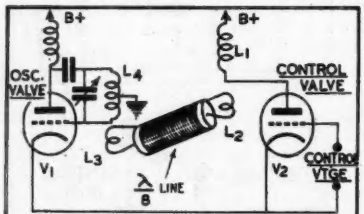

Fig. 5. λ/8 line circuit for U.H.F.

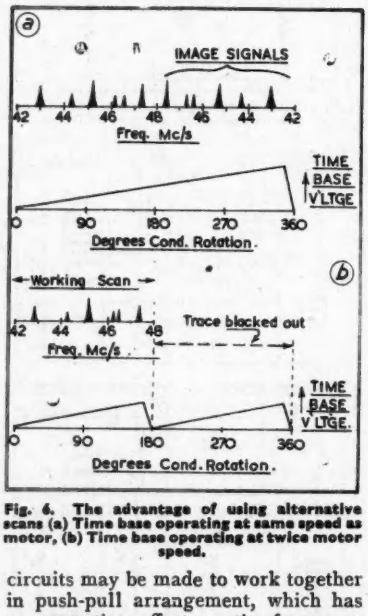

Fig. 6. The advantage of using alternative scans (a) Time base operating at same speed as motor, (b) Time base operating at twice motor speed.

circuits may be made to work together in push-pull arrangement, which has a summation effect on the frequency excursion. (*See* Fig. 4). Due to the fact that:

$$X_c = \frac{1}{\omega C} \text{ and } X_L = \omega L,$$

it follows that if a capacitative circuit and an inductive circuit are driven in push-pull (*e.g.*, grids in anti-phase) the frequency change due to the anode circuits (in parallel) is additive. Thus, the capacity and inductance are both varied simultaneously, giving a greater excursion that would be obtained with one reactance valve. Actually, this circuit gives considerably less than twice the excursion expected with a single valve arrangement. The results were not considered satisfactory for the Etherscope, which requires an excursion of some 16 per cent. at 50 Mc/s.

The Eighth-Wave Line

It is known that the distant end of an eighth-wavelength line appears as a pure reactance when the near end is terminated in its characteristic impedance. This phenomenon may be used to produce frequency modulation in the following manner: (*see* Fig.5). V_1 is the R.F. oscillator and V_2 is the control valve. The turns ratio of L_1 and L_2 is such that the low anode impedance of the triode is correctly matched to the characteristic impedance of the line. Under these circumstances, L_2 appears reactive. Now, if a saw-tooth voltage is applied to the grid of the control valve, its anode impedance will change in sympathy, causing a periodic mis-match into the line, which in its turn causes a variation of reactance appearing in the oscillator tuned circuit.

This circuit is obviously most advantageous in the U.H.F. bands where the performance of the ordinary reactance valve is limited by stray capacity. Further, this arrangement is more conveniently applied to the U.H.F. bands because the line then assumes reasonable proportions. It is not, however, well suited for the Etherscope.

Suitable R.F. Oscillator

Normally, it is desirable to use the Etherscope in conjunction with some given receiver. But the type of local oscillator is of some importance. It is necessary to use the available reactance change in the most profitable way, if maximum excursion is to be secured.

For instance, when capacitative reactance circuits (such as in Fig. 2b) are used, it is obviously desirable to employ a high L/C ratio in the oscillator tank, so that the varying capacity effect represents a large proportion of the total tuning capacity. This, however, has the disadvantage that as the main tuning condenser is varied, the percentage frequency excursion will alter, being maximum at the high frequency end of the band. Where this is undesirable, the inductive reactance system suggests itself.

For certain applications, it may be desirable to obtain a constant frequency excursion, independent of

mean frequency. This calls for a heterodyne oscillator.

Whichever system is employed, it is important that the reactance developed be shunted across the whole of the oscillator tank circuit. This cannot be done with Hartley and Colpitts oscillators, and so it is desirable to use circuits that are grounded at one end, such as electron coupled, tuned grid, and negative transconductance arrangements.

Wide Band Requirements

When the deviation ratio is low, it is permissible to change the frequency of the local oscillator alone, and use band pass (or staggering) on the R.F. stages. But the Etherscope demands a much greater deviation ratio than bandpassing will permit. Consequently, whatever the merits of the various electronic circuits may be, the arrangement becomes clumsy when each R.F. circuit has to be similarly treated.

Mechanical Frequency Modulation

The various electronic circuits having proved themselves unsuitable for the wide band requirements, it was decided to recourse to the less classic but simpler system; the motor-driven tuning condenser. Greater frequency excursion is possible, linearity is good and the action is positive.

There are, however, several disadvantages, the first being the extreme care required in the mechanical design and construction.. The condenser must be capable of fairly high rotational velocity, it should, therefore, be dynamically balanced. Wiper contacts to rotor plates are out of the question, and so split stator construction is essential, the rotors being in the air. The motor must be free from vibration, or else modulation effects, microphony, and instability may occur.

Also, synchronism must be attained between time base periodicity and condenser speed. This is usually done by means of switch contacts operated from the motor shaft, which are connected via a battery to the oscilloscope synchronising circuit.

Since the rotating condenser passes through maximum and minimum capacity twice per revolution, the second half revolution is not required, and should not appear on the screen. (Fig. 6a.) To prevent this, the oscilloscope may be blacked out for the second half revolution of the condenser, the base line recentred, and amplified to occupy the whole tube. A better method is to operate the time base at twice the motor speed, synchronise every other cycle, and black out every other scan of the beam. (Fig. 6b.) It is desirable to

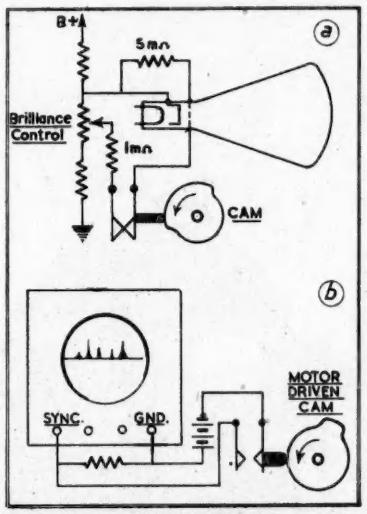

Fig. 7. Synchronising and blackout circuits, (a) Blackout circuit, (b) Synchronising cam and circuit.

black out every other scan, primarily to make the brilliance of the vertical signals equal to that of the base line, and secondly to prolong the life of the tube.

The Final Design

This mechanical system proved to be suitable for the Etherscope.. A frequency excursion of some 15 per cent. was obtained on the 45 Mc/s. band. The condenser consisted of an aluminium alloy cast frame measuring 4½ by 2¼ by 2 inches, the stator plates being mounted on ceramic rods, and the rotor spindle was mounted on ball races. The split stator plates were mounted on ceramic rod supports. All plates were machined from the solid. Three gangs were used, and the centre section was set diametrically opposite the other two which, together with a small counterweight, served to balance the shaft. A shock absorbing coupler was used to couple the motor to the condenser. A Hallicrafter S.20.R. receiver was used, its band spread gang being replaced by the rotating condenser. The motor was located at the back, behind the set.

Two sets of contacts were used, one to black out every alternate scan, and the other to provide synchronisation for the trigger valve. Both were actuated by cams on the motor shaft.

The circuit for blacking out alternate scans is shown in Fig. 7 (a). With contacts closed for the unwanted scan, the brilliance control is retarded to minimum. When the contacts are open, the brilliance control is disconnected, and a suitable voltage from the main H.T. potentiometer taken direct to the grid of the tube. It is necessary to complete the grid-cathode with a 5 megohm resistor. The one megohm resistor acts as a safety device, should the contacts accidentally become grounded, but it does not upset the dimming voltage from reaching the grid.

The synchronisation is accomplished by arranging a battery to be switched into the sync-ground circuit, so that it receives a momentary pulse for every revolution of the condenser. (Fig. 7b.) Since the time base operates at twice motor speed, it receives the synchronising pulse every second sweep. It is necessary to adjust by trial and error, the moment at which the pulse takes place, with respect to the condenser position.

It was desirable to vary the bandwidth, and this was done by fixing a midget 100 μμF. air spaced padding condenser in series with each section of the rotating condenser. The three were ganged, and comprised the bandwidth control.

The Etherscope is an instrument worthy of further development, and it will attract the attention of many experimenters. When perfected, it will undoubtedly find many applications in police, aircraft, amateur and station monitoring fields.

Complexity

. . . The greatest man-made complexity is probably that of a machine-switching telephone system. Like the atom, it has few different kinds of parts, but of each it may contain tens of thousands.

In a rapid but guided evolution these systems have adapted themselves to an increasing variety of situations.

They embody brains—several each in the larger systems—which can count, interpret, and record and then initiate whole sequences of actions after selecting the suitable means and verifying the possibilities.

Even more, these brains have powers of self-analysis such that in the rare case of their mental breakdown, they can relinquish the job to fellow organisms and retire from active service. As their cerebral processes fail, their autonomic nervous systems act to free them from entangling connexions with subscribers' lines and to signal to a human attendant. When this doctor comes he finds that they have recorded for him a correct diagnosis of the trouble.

Could one ask more intelligence in an electrical device—or expect a further evolution of its abilities? You and I might be tempted to answer "No." But that will never be the answer as long as there are telephone circuit designers.

Miller—*Bell Lab. Record*, Jan., 1944.

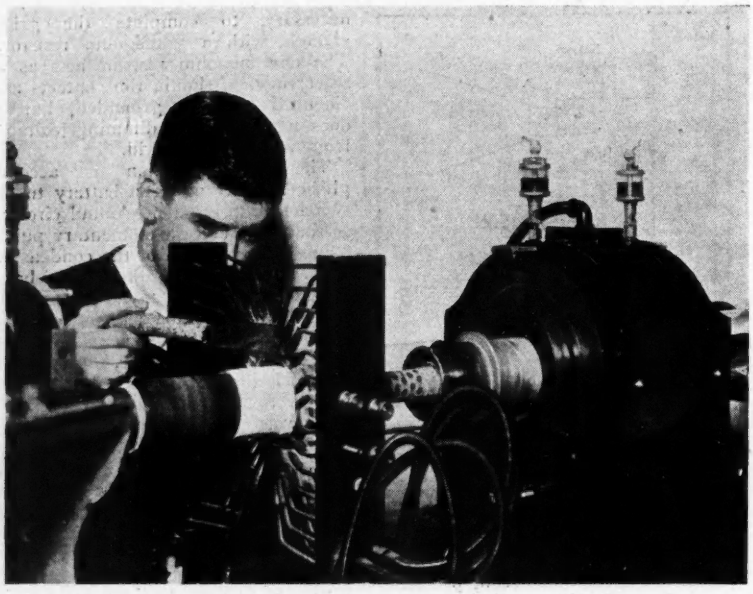

Fig. 8. Sealing-in Water Cooled Valve.

The Technique of Glass Manipulation

By G. A. PERCIVAL,
A.Inst.P.

Part 2.
(Conclusion)

IN manipulating glass by hand, annealing becomes second nature even in making a simple joint (which to the amateur, is not so simple and oftens turns out as a distorted lump of glass with a leak). By watching a craftsman it is obvious that he senses a certain "feel" of the "metal" as he warms and softens it, not too much, nurses it into shape with intermediate annealings, and then allows it to cool very slowly. In this, all the broad principles of glass manipulation are involved. Now consider what happens.

Two pieces of tubing have to be cut and squared up. The ends are warmed, melted, brought together and gently pressed to make a seal. Further heating and a slight pull smooths the outside but constricts the bore. By again heating and blowing into one end while the other is closed with a cork—or by the finger—a bubble is blown or contracted at will until a smooth joint is obtained. Such things cannot be learned from a correspondence course, though it is possible to suggest the reasons for failure, and in practice one of the great difficulties is due to thickening of the glass.

Machine Sealing

To follow this simple example a stage further, consider what is involved in sealing a bulb on to a stem by mechanical means. Fig. 6 shows the progress of the operations as carried out with a 10-head semi-automatic machine, the last two stages on which are not shown and will be discussed later. A is a cradle to hold the bulb, B. T, is a "bent stem" joined to the side of the flange, instead of being in the pinch, to give additional strength. D, C and K, indicate the parts of the stem pin which holds the stem in position during sealing. In operation the complete table on which all the heads are fixed, rotates, each head also rotating or remaining stationary according to design. Now it is obvious that if the fires F are not properly adjusted, melting will be irregular, one stage with the next, up to position 7 where the bulb becomes sealed to the flange and the neck of the bulb falls away; but a thin film of glass still remains, forming a pocket between T and C, so that when air is blown through the openings of the spindle at D, a thin bubble is formed which bursts and leaves only a tail of glass which is melted by the fires.

For comparison, to show how the same technique is applied to other types of apparatus, the sealing of miniature lamps and that adopted for large valves is given in Figs. 7 and 8, but, as already indicated, a joint is not sufficient. The joint, or rather the rim of glass formed by the joint, must be smoothed out. To do this, the craftsman's trick of "pull-down" is applied mechanically, as shown in Fig. 9.

Now it will be seen from Fig. 6 that as the glass melts, the angle which is formed is dependent upon the width of flame directed on the bulb. If the diameter of the flange is too small, an acute angle will result with a consequent thinning of the neck. With a pull-down it is neither the neck nor the flange, but the joint which is thinned out.

On a high-speed machine such as that shown in Fig. 10, the same principle is applied even though the parts are fed, assembled and removed automatically at a speed of anything up to 10,000 a day, so that a temporary breakdown represents a serious loss. When 24 heads are involved, it will be seen that chaos may result from some irregularity in the material or setting of the fires.

Although a good deal of breakage is caused in every factory by lack of standardisation, much may be avoided by applying the right technique. Transport and handling breakage are subjects outside the scope of this article, but sealing breakage can be analysed and placed within one of three main groups, the most common of which is cracked seals.

A cracked seal must not be confused with cracks in sealing due to defective stems. A cracked flange is often treated as a loss at sealing when in reality it is a defect of a previous operation. When the crack occurs in or outside the seal proper, it is more likely to be due to wrong fire-setting for a particular time cycle. The temperature reached during sealing should be that at which the glass flows without running, and the width of flame should be such that the angle of sealing is obtuse rather than acute. With too small a flange this is not

possible, but even with the right flange, an acute angle will be formed if the sealing fires are directed too far above the level of the flange. Any conditions which forms a thin wall on a thick flange will cause cracks, just as will a thick seal if the pull-down is not sufficient; but a thick seal will also result from over melting, for which the pull-down is no remedy.

With many types of machine the pull-down is a hand operation performed at the moment of removing the bulb from the cradle. A good operator will work with almost mechanical precision, but if for any reason the glass becomes too cold, strains are introduced by the fact of having to force the bulb into position. This applies particularly in the case of soda-glass which has a sharp solidifying point.

Even with automatic machines, if the pull-down is too severe, cracks will occur. The object is to equalise thickness so that strains, if introduced, are immediately removed. In the absence of strain, cracks will not develop, though under manufacturing conditions one often experiences sudden bursts of shrinkage which disappear as mysteriously as they begin. Perhaps this happens more frequently under war conditions when speed and production are more important than appearance. Material is not of that high quality usual in normal times, and to some extent, these epidemics may be due to a general lower standard of finish even though electrical characteristics have to meet a more exacting specification. Lop-sided bulbs and oval flanges are not conducive to low breakage or good appearance, yet often as not an increase in shrinkage may result from some insignificant cause such as a draught on a hot day, or bulbs touching one another on a cold day; small points, but nevertheless, important.

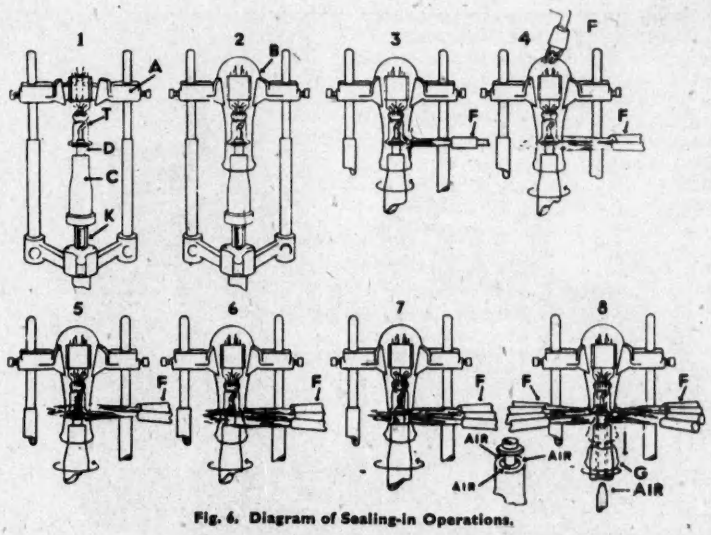

Fig. 6. Diagram of Sealing-in Operations.

Metal-Glass Seals

In all electrical devices of the kind under consideration, metal-to-glass seals are an integral part of the construction. The simplest illustration is that of the ordinary lamp with two electrodes (or "leading-in wires") of "copper-clad" running through the stem. More complicated apparatus may require the use of stranded wire, tungsten rod, copper disks or tube, often of considerable size. The metals may be platinum, platinum substitutes, tungsten, molybdenum, copper or nickel-iron alloys according to circumstance. On account of cost, platinum is rarely used except where there is risk of chemical attack.

Success with copper-clad depends on the quality of wire, the composition of the glass and the time-temperature factors in manipulation. The first point may be generally disregarded, except where material has been in stock for a long time. The composition of the glass is not critical. It is in manipulation that difficulties arise, particularly in experimental work, and sometimes even the factory engineer is bred with that familiarity which fails to recognise the cause of cracked stems when the colour of the electrodes might offer a solution. In addition to actual breakage there is always the possibility of stem leaks if the proper technique has not been applied.

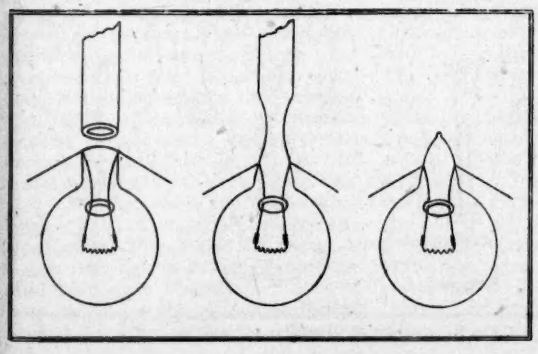

Fig. 7. Diagram of Miniature Sealing-in.

Failures apparently due to the quality of copper-clad are more likely to be caused by some defect in welding, for each electrode is a composite of three wires. Only about 5 mm. of copper-clad are actually used in an ordinary stem, one end being joined to copper wire and the other, to nickel, by butt welding. Copper facilitates soldering to the base or cap contacts. Nickel gives a rigid support for mounting the construction; but if either of the welds are too big, leaks or cracks will develop in the stem.

What comes to very much the same thing is setting the electrodes too high or too low in the stem-block. This results in one weld being in the middle of the pinch with the other end outside, so that rigidity is sacrificed or leaks occur at the weld knot. A similar condition is created if the jaws which form the pinch are too wide or too narrow in relation to the length of copper-clad. A wide pinch in a lamp stem is less fragile than in the case of a valve stem which carries, not only electrodes but six or seven support wires of fairly heavy-gauge nickel, which for reasons of mechanical strength are often made of channel strip. Similarly in a lamp stem, if the glass rod—which serves the same purpose as metal inserts in a valve—projects too far into the flange tube during stem-making, cracks will occur for very much the same reasons, as the rod used is generally of a harder material than that of which flange tubing is made.

From this it will be understood why standardisation at every stage is

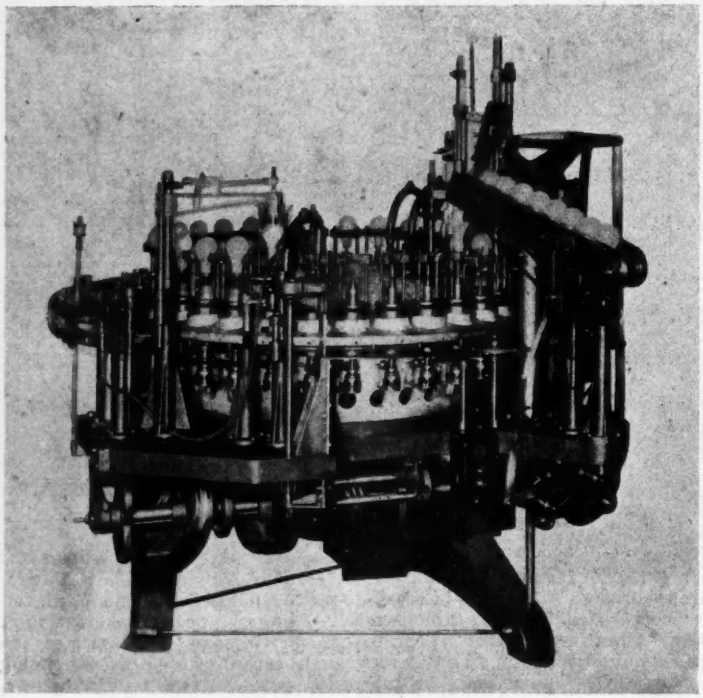

Fig. 10. High Speed Sealing-in Machine.

important. It is not sufficient to make a table showing the setting of a machine. Actual gauges are preferable to any system of measurement, so that the stops in the stem head, which determine the position of the electrodes, inserts (or glass rod), flange, and exhaust tube are always in exactly the same position for a given type of stem.

Leaks

One of the greatest difficulties, so far as the electrodes are concerned, is adjusting the fires so that proper wetting of the copper-clad is obtained before the pinch is made. If conditions are such that either the glass or copper-clad is overheated, leaks will occur at, or after, exhausting.

There are other reasons for leaky stems, such as bad adhesion between the core and sleeve of the electrodes, but in the majority of cases leaks result from some error in stem making, though not necessarily an error of the stem maker. Provided fires are carefully regulated, and the distance between the straight end of the stem tube and the stem block is adjusted to a set standard, any bubbles on the copper-clad warrant an immediate check on the source of glass supply to see if material has become mixed. A rough test for this is to melt a sample of doubtful glass with one of known good quality in a bunsen flame and draw them out to a fine thread. Any difference between the two will show as a curve, the one with the smallest contraction being on the outside of the segment.

Where conditions are normal and leaks still persist, it may be due to insufficient flux on the copper-clad, characterised by black spots where the copper has oxidised. Ordinarily, good copper-clad should have a smooth, rose appearance changing to pink when pinched in glass. Under-heating will prevent proper wetting. Over-heating will cause burning. The height of the stem tube above the stem block should be such that the electrodes reach a dull red heat just at the moment of pinching.

Naturally, the size of electrode is determined by the amount of current which is to be passed, and though anything up to 20 amps. may be used with a single strand wire, beyond this it is preferable to adopt a different technique. In some respects this is essential, as heavier mechanical construction is usually associated with increasing current. A perfectly good vacuum seal can be made with fine copper wire, provided the current is only in the nature of milliamps, but where there is any appreciable load—particularly at high temperature—careful selection of method and material is essential.

Large Seals

All glass-to-metal joints depend on good adhesion and minimum strain. Glass with a lower expansion than that of the metal to which it is sealed, may be used when the temperature remains normal, as the strain is equally distributed; but unless the glass has a greater expansion than the metal, with increasing heat the radial strains around a wire will be unequal. In aiming at the ideal condition, where there is no strain even with changing temperature, chemical adhesion, thermal expansion and electrical conduction are complementary. The permissible latitude in any of these factors is determined by the design and ultimate use of the apparatus.

When adhesion depends on an oxide layer the co-efficient of expansion of the metal and glass need not necessarily be the same, provided the difference is compensated for by other means.

In the classic method devised by W. G. Housekeeper of America, for glass-to-metal joints, a copper tube is machined down to a knife edge. After forming a coating of copper oxide by heating, borax (or Pyrex, as the case may warrant) is melted on to the surface, using particular care to limit

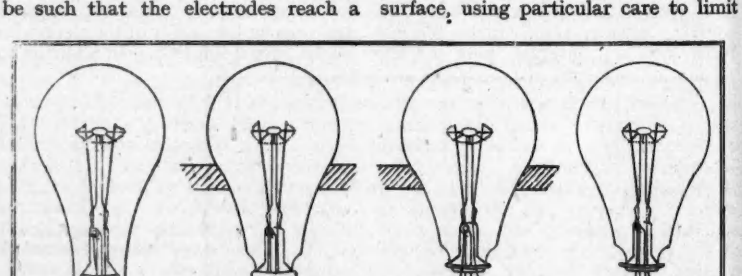

Fig. 9. Diagram of "Pull-Down."

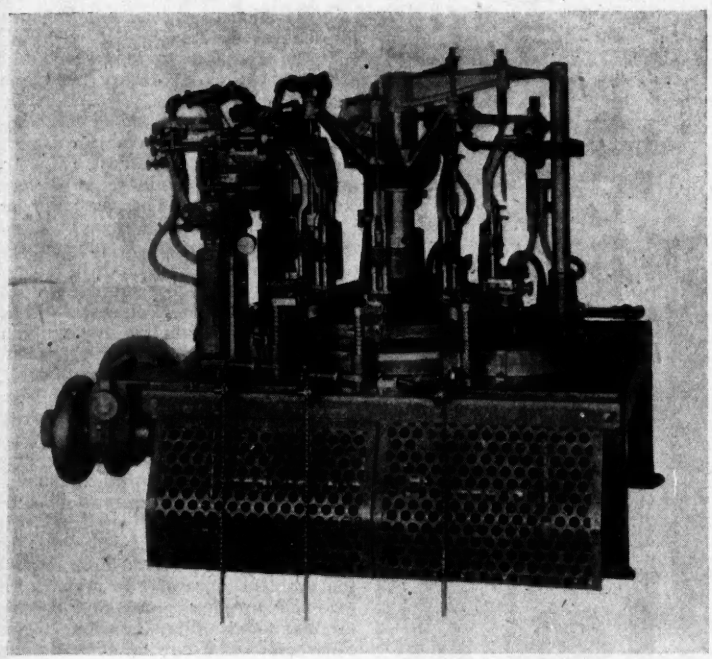

Fig. 11. Inserting Machine.

the area to a rim below the end of the tube. A glass tube is then spliced with the copper and heated until the flux melts, after which the joint is cooled very slowly.

A similar technique is used in sealing a disk of metal on the end of a tube, and provided the flux is kept away from the circumference of the copper, very satisfactory joints can be obtained.

Both the above methods are of established commercial importance, but in recent years, research has been directed toward finding alloys which have similar expansion characteristics to those of glass, with a view to eliminating the disadvantages of the copper-to-glass seal. Co-efficient of expansion is not the only criterion of efficiency. Even at ordinary temperatures many types of glass show a slow contraction after annealing, which is the reason for careful selection in the manufacture of thermometers. A glass-to-metal seal, therefore, is as much dependent on the time-contraction factor at 20°C., as on the co-efficient of expansion between that temperature and melting point.

Numerous alloys have been suggested for electrodes and connexions, but few have those properties required for success. Porosity in the metal or a slow leak due to contraction of the glass may have disastrous effects in large valves, particularly when heated too quickly after having been in store for a long time. If, on the other hand, both glass and metal have the same contraction co-efficient, any seal will remain substantially free from strain over a wide range of temperature. This can be effected only by close control in the manufacture of both materials. So far as glass is concerned, the products of the Corning Glass Company are renowned for regularity, and it is not surprising that the General Electric Company of America should have developed alloys to match Corning standard glasses. "Fernichrome" and "Fernico" are two typical examples. "Kovar" is a similar product of the Westinghouse Company, America. In all these cases the expansion of the glass and appropriate alloy are nearly the same, allowing for the fact that ordinary glass increases in expansion near its melting point. Seals made with such alloys are therefore unstrained under conditions of normal temperature and do not require the special technique of glass-to-copper seals.

Copper-clad, as the name implies, is a composite wire made by sweating a copper tube on to a core of nickel-iron with silver. The copper coating gives not only a surface for the adhesion of the glass, but, greater electrical conductivity, a method which can be applied to tubes of larger diameter for water-cooled valves. In this case, however, when using a nickel-iron tube, difficulties sometimes arise in obtaining satisfactory adhesion between the alloy and the copper ring; perhaps several inches in diameter. This may be overcome by depositing copper by electrolytic means. The strength of the joint may be gauged from the fact that at one time this method was used for depositing copper rings on shell noses. The copper is pure, free from cracks, and can be built up to any thickness.

Support Wires

Between these extremes of small lamps and large valves, seals of an intermediate size are often required where insulation is of greater importance than conductivity. The simplest example is that of the fine, radial wires which support the coiled filament in a lamp. The diameter, length inserted, and the conditions under which it is inserted into the glass "stud," all contribute to the over-all efficiency in manufacture and service. For ordinary purposes molybdenum wire is used, but when anything involving more than 1,000 watts is contemplated, tungsten—with special glass—is preferable.

Whether or not inserting is done by hand or machine, some care is necessary to obtain the best results. In the first instance, wire must be annealed to a condition in which it hangs straight when taken from the spool. Without this, regular machine-feed is impossible.

Inserting machines are of two kinds, those in which the wires are set in the stud one at a time (Fig. 11). and those in which all the wires are projected simultaneously to a point where the stud is then formed. In either case, but more particularly in the former, if the glass is over-heated a characteristic

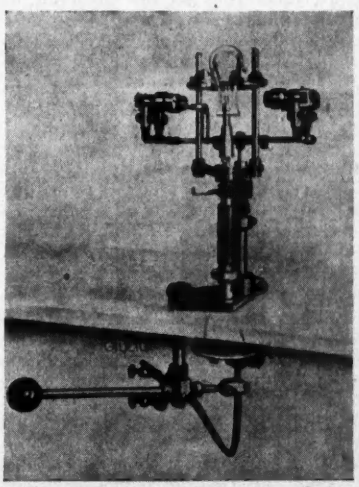

Fig. 12. Laboratory Machine for Glass Manipulation.

umbrella-shaped stud will be formed —and probably crack. This may not be due to incorrect setting of the machine, for any variation in the diameter of the glass rod will obviously cause a difference in the size of the stud, which may be over-melted—causing blackening or devitrification—or under-melted so that the wire is forced into already cold glass.

Support wires in valves present a different problem as they are virtually part of the stem and are required to hold a much heavier construction than a filament weighing only a few milligrams. In large valves and X-ray tubes the weight may be in terms of kilograms, and as temperatures of over 1,000°C. are sometimes reached in exhausting, any support must be designed with a view to mechanical strength under conditions of extreme heat. This limits the selection to tungsten and molybdenum, or alloys of nickel which have a low vapour pressure. Pure nickel has too high a thermal conductivity, but alloyed with manganese, chromium or iron, not only is the temperature of the stem reduced, but, the mechanical strength is increased. Within the confined space of an ordinary valve stem, however, the inclusion of several additional wires introduces considerable strain with the possibility of current leakage. In extremely small valves the latter difficulty is overcome by using a " ring seal " in which the wires are inserted on the circumference instead of across the diameter of the stem ; but valve *design* is not under consideration. The practical difficulty is to obtain a multiple-wire seal to glass without cracks.

Previous emphasis of careful grading will now be better appreciated, for very small differences in the diameter of glass tubing and wire may result in a sudden over-balancing of the safety limit. When cracks occur, therefore, it is useful to check the total weight of the finished stem. The differences may be surprising.

Since valve inserts are usually an alloy and not a composite material like copper-clad, if too much is imbedded in the glass, cracks will result. To ensure rigidity with a minimum length of wire in the stem, good wetting is essential. An under-melted pinch on nickel wire is not conducive to good results. On the other hand, if the nickel is pre-wetted, or coated with a flux, the margin of safety is much greater. In certain American works this is accomplished by spraying a flux on the end of the inserts in the same way that electrodes for small " auto " lamps are treated. As a mechanical process the cost is negligible. The saving, apparently, is well worth while.

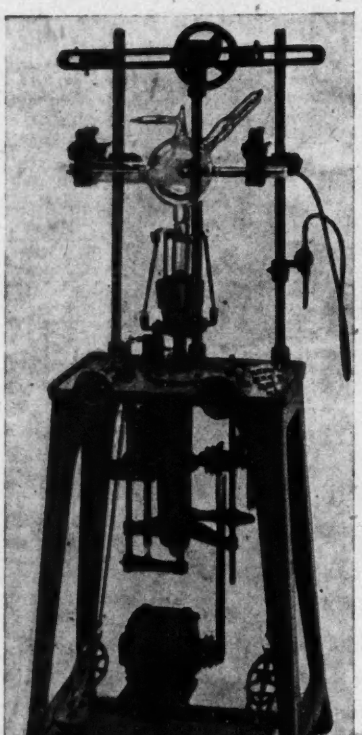

Fig. 13. Semi-industrial Sealing-in Machine for Special Purposes.

In some respects the technique is similar to the Westinghouse-Stupakoff method of joining metal and porcelain.

A final reference and re-emphasis to the subject of annealing cannot be out of place, for in laboratory and industrial work more breakage probably occurs from a neglect of this factor than from anything else. Experience has shown that in annealing ovens with a pyrometer reading 450°C., the stems never reached more than 350°C. It may not arise in well-designed equipment in a well-organised factory—but it may ! It costs little to make a regular check with indicator paint.* When this was done in a world-famous factory a difference of 30°C. was found between the pyrometer reading and the temperature of the stems being annealed.

Laboratory Technique

What has been said in reference to machine operations applies equally well to laboratory work, the consideration of which has been left until now for definite reasons.

In the first place, there is a good deal of literature on laboratory technique already in existence. Secondly, by understanding something of mechanical methods, glass-blowing for experimental purposes is simplified. To make a stem by hand requires very considerable skill. The same applies to almost any operation involved in making experimental valves ; but by applying industrial methods to laboratory work, satisfactory apparatus can be made much more economically than by attempting craftsmanship without a craftsman's training.

Within the space of a small room, valves can be made right through from the point at which tube is cut for flanging, finishing at exhaust and basing. In development work this avoids interference with routine manufacture and enables observation to be kept on reactions at every stage. It eliminates a good deal of tedious labour and allows one to devote more time to the problem in hand. In addition, it gives one an opportunity of becoming familiar with glass-blowing which otherwise could only be derived from long apprenticeship.

Apart from this, mechanical methods of assembling ordinary apparatus for the laboratory are more satisfactory than attempting the same work by hand. Naturally, spirals and intricate joints remain a job for the expert, but a good deal of apparatus can be made on simple machines by a novice, after very little experience.

An example of this is the machine shown in Fig. 12, where a rotating, vertical spindle, driven by a small motor is adapted to take interchangeable heads for stem-making and sealing ; or joining tubes, bulbs, etc. Very little ingenuity is required to adapt such a machine to many purposes, but where more complicated, assembly is contemplated, the apparatus must necessarily be more elaborate and borders on the semi-industrial. Fig. 13 is such a machine, and though an X-ray tube is shown in position for sealing, the flexibility is obvious.

Whether in hand or machine work, the problems in manipulating glass are very much the same. Where troubles arise, reference to the text of this article should suggest a possible cause and remedy.

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The Comparative Strengths of Ceramic and other Insulating Materials

by Dr. Ing. E. ROSENTHAL

IN the February issue of this journal, Mr. A. E. L. Jervis compared very briefly some characteristics of porcelain with those of compressed laminated bakelised wood. The present author felt that the few figures quoted did not give a comprehensive view of the characteristics of ceramic materials, and gives in the attached tables a résumé of the more important electrical and mechanical characteristics of ceramics compared with those of other types of insulators.

In a book which will shortly be published,* the author sets out in detail the influence of test methods on the values obtained. Not all the values shown in the following tables are found by the same test methods, and allowance for this fact has to be made. When comparing ceramic and organic insulating materials it has, furthermore, to be borne in mind that the electrical and mechanical characteristics measured at room temperature and in room atmosphere do not fully illustrate the different nature of the various materials. These tests have to be supplemented by others made at higher temperatures and/or after treatment for prolonged periods in humid atmospheres, and these show more clearly the different natures of ceramic and organic materials.

It is not possible in this article to deal with the question in detail, but having due regard to the limitations outlined above, the subsequent tables will be of interest:—

In the tables showing the mechanical characteristics the values are given in kg. per sq. cm., or in lbs. per sq. in. and in kg. cm. per sq. cm. and ft. lbs./per sq. in., in accordance with the original publications and the conversion formulæ are given.

Ceramics have certain advantages over organic materials. All of these are not brought out by the tables given in this article.

One advantage is that for all practical purposes ceramic materials do not deteriorate in service. Tests have been carried out extending over many years to prove this point.

This characteristic results from the fact that dense ceramic materials are non-porous. Moreover, they are not affected by humid amosphere and the chemicals found therein. They do not alter under the influence of an electric field and corona discharges, until the breakdown values are reached.

Behaviour of Ceramic Materials at Elevated Temperatures (Breakdown Strength)

The figures are given in Table 9 overleaf.

Volume Resistivity at Elevated Temperatures (T_e Values)

The T_e values for volume resistivity (*i.e.*, the temperatures in °C. at which a 1 cm. cube has a resistance of 1 megohm) are very instructive.

The American Lava Corporation has published the values given in Table 10.

Of dense ceramic insulating materials pure sintered alumina has most probably the highest T_e value.

Hardness of Ceramic Materials

The great hardness of ceramic materials is another of their advantages. For purposes of comparison, bearing in mind that the hardness value of unfired talcum, the softest ceramic material is 1, and that of diamond—the hardest mineral—10, the figures of Table 11 are remarkable.

They indicate the great hardness of ceramic materials, which hardness can be enhanced by the addition of suitable glazes. It is not possible, for example, to glaze plastic cups or beakers, and this is one of the disadvantages of this type of ware. The absence of glaze permits of discolouration and, moreover, the softness of the material makes it liable to damage by scratching.

Resistance to Temperature Shock

One of the less favourable properties of ceramic materials is their tendency to crack when suddenly heated. This is all the more marked when the sudden temperature change is restricted to part of the article only.

The thermal shock resistance of a material is the better the lower its thermal expansion and the greater its thermal conductivity. It is, of course, assumed (a) that the material is homogeneous; (b) that a suitable glaze is correctly applied.

It is difficult to find an appropriate unit for expressing thermal shock resistance, because this varies so extensively, depending on the shape of the article.

Porcelain laboratory crucibles, for example, are tested in the following manner. They are partly filled with water and then placed on an open Bunsen flame. After the water is evaporated the flame is still kept on until the crucible is red hot. The crucible is then placed on a cold metal plate. Good quality crucibles withstand many such cycles.

Porcelain crucibles are not, strictly speaking, low expansion bodies. They owe their great shock resistance to their extremely uniform structure.

For larger thick-walled articles, such as insulators designed to withstand heat suddenly developed by large power arcs, bodies possessing very low thermal expansion are most suitable.

It was originally very difficult to find suitable glazes for low-expansion ceramics, but this problem has recently been solved.

If the thermal conductivity of such bodies is increased by adding suitable ingredients the thermal shock resistance can be further improved. There is every reason to believe that before long new ceramic materials will come on the market, superior in this respect. This is not only of great interest to the electrical, but also to the chemical industry.

Table 12 gives the thermal expansion of ceramic bodies, and Table 13 the conductivity.

In conclusion, it is hoped that the brief summary of ceramic characteristics given in this note will give the reader some idea of the extreme versatility of the ceramic range.

* "Porcelain and other Ceramic Insulating Materials," by E. Rosenthal, (Chapman and Hall).

Electrical and Mechanical Properties of Po

TABLE 1

Power Factor at Room Temperatures

	Power factor at 60 c/s.	Power factor at 10^7 c/s.
Wood floor filled resin	0.04—0.3	0.035—0.1
Fabric filled resin	0.08—0.3	0.04—0.1
Asbestos filled resin	0.1—0.3	0.005—0.1
Laminated phenol resin	—	0.02—0.08
Cast phenolic resin	0.042	0.038—0.042
Styrene	0.0003	0.0003
Porcelain	0.017	0.006
Steatite (normal)	0.003	0.002
Steatite (high frequency) ...	0.001	0.0001
Glass	0.03—0.005	0.002—0.006
Mica...	0.02—0.003	0.006—0.002
Frequelex	0.001—0.002	0.0001—0.0002

As is generally known, the power factor is more often expressed in percentage, or as power factor tan δ since many noughts, particularly in the figures for the low-loss materials are inconvenient to work with. For example, the power factor 0.0001 can be written as 0.01% or as tan $\delta = 1 \times 10^{-4}$.

TABLE 2

Volume Resistivity at Room Temperature

	Megohms per cm.³
Quoted from American A.S.T.M. Standards	
Ivory	2×10^{12}
Celluloid	2×10^{4}
Marble	1×10^{5}
Plate Glass	2×10^{7}
Amber	5×10^{10}
Fused quartz	5×10^{12}
Ceresin	5×10^{13}
American Lava Corporation	Ohms per cm.³
Various Steatite products	1×10^{14}
Bullers	
Frequelex	1×10^{14}
Quoted from German V.D.E.	
Porcelain	1×10^{14}
Mica	1×10^{15}—1×10^{16}
Mycalex	1×10^{13}—1×10^{14}
Fused quartz	1×10^{17}—1×10^{18}
Bakelised paper	1×10^{12}
Bakelite	1×10^{9} —1×10^{12}
Polystyrol	1×10^{13}

TABLE 3

Surface Resistivity at Room Temperature

Material	Surface resistivity—Megohms per cm.² at 25 per cent. relative humidity	at 90 per cent. relative humidity
Ivory	10,000	50
Celluloid	100,000	1,000
Marble	100,000	10
Plate Glass	100,000,000	20
Amber	1,000,000,000	100,000
Fused quartz	1,000,000,000	100
Ceresin	100,000,000,000	100,000,000,000
Porcelain glazed	40,000,000,000	100,000

TABLE 4

Dielectric Breakdown Strengths (50 c/s) at room temperature.

British High Tension Insulator Porcelain ...	kV/cm.	250—300
Thin slices	Volts/mil.	640—760
Frequelex and Frequentite	kV/cm.	240—300
Thin slices	Volts/mil.	670—760
Titania High Resistivity Bodies... ...	kV/cm.	100—120
Thin slices	Volts/mil.	250—310
Alsimag (American Lava Corporation)		
Clinoenstatite Bodies	Volts/mil.	225—240
Test disk ¼" thick		

These values are lower than those published by British and German Authors. This is to be explained by the greater wall thickness of the test specimens and the different arrangements of the electrodes.

German Publications			
Porcelain	Thin slices	KV/mm.	34—38
Steatite	,,	,,	35—45
Mica...	,,	,,	70
Mycalex	,,	,,	15
Fused silica	,,	,,	25—40
Bakelised paper	,,	,,	20—35
Polystyrol	,,	,,	±50
Wood flour filled resin	Volts/mil.		300—500*
Fabric filled resin	,,		300—450
Asbestos filled resin	,,		250—400
Styrene	,,		500—700
Hard rubber	,,		250—900

* "Plastes"—Plastics in Industry.

TABLE 5

Impact Strength

Steatite (American Lava Corporation) ...	1.8 and 2.1 ft. lb. per in.²
British High Tension Porcelain	0.84—0.98 ft. lb. per in.²
	1.82—2.1 kg. cm. per cm.²
Frequentite and Steatite	1.3—2.3 ft. lb. per in.²
	2.8—4.5 kg. cm. per cm.²
German Publication (V.D.E.)	
Porcelain	Kg. cm./cm.²
Extruded cast	1.8—2.2
Pressed	1.3—1.6
Steatite	3—4
,, high frequency (low-loss)	4—5
	Shock resistance ft. lbs./in.²
Mycalex	1.5—2.8
Cellulose	0.3—1.0
Phenolic resin wood filled	0.3—0.5
Phenolic resin fabric filled	0.5—2.5
Laminated phenolic paper filled ...	0.3—3.8
Laminated phenolic fabric filled ...	0.8—7.5
(2.12 kg. cm. per cm.² = approx. 1 ft. lb./in.²).	

TABLE 6

Tensile Strengths

British Publications	kg. per cm.²	lbs. per in.²
Porcelain	300—400	4,200— 5,400
Frequentite "S"	400—500	5,700— 7,100
Frequentite	550—850	7,800—12,000
Frequelex		8,500—11,000
American Lava Corporation		
Various Clinoenstatite materials ...		8,500—10,000
German Publications	Kg. per cm.²	
Glazed porcelain	300—500	
Unglazed porcelain	240—320	
Steatite	550—850	
Steatite high frequency	550—950	

(kg. per cm.² = 14.223 lbs. per in.², or 100 lbs. per in.² = 7.03 kg. per cm²).

To facilitate comparison with other insulating materials, the following data may be of interest :—

	lbs. per in.²
Mycalex	6,600— 7,300
Phenolic resin wood filled	4,000—11,000*
Phenolic resin fibre filled	6,500— 8,000*
Phenolic resin asbestos filled	4,000—10,000*
Laminated phenolic paper base	7,000—18,000*
Laminated phenolic asbestos base	7,000—18,000*
Laminated phenolic cloth base	8,000—15,000*
Bakelised laminated wood	32,000—47,000
	tons per sq. in.
Celluloid...	2¼
Cellulose acetate	3—5
Polystyrene	2½—3
Polyvinyl chloride	4½

* "Plastes"—Plastics in Industry.

Porcelain and other Insulating Materials

TABLE 8

Flexural Strengths—Modulus of Rupture

Porcelain		kg. per cm.²
	Extruded	
	Glazed	900—1,000
	Unglazed	400—800
	Pressed	
	Glazed	600—700
	Unglazed	300—600
Steatite—varies between		1,200—1,600 kg. per cm.²
Mycalex		1,000
Fused silica		700
Clinoenstatite (Steatite Bodies)		1,200—1,600
Titanium bodies		900—1,500
Bakelised bodies		1,500
Polystyrol		1,100

(The above mentioned figures are quoted from German literature).

From American literature, the following values are quoted :—

	lbs. per in.²
Clinoenstatite bodies	18,000—22,000
Titanium bodies	20,000
Porous talcum bodies	8,000—9,000

TABLE 9

Dielectric Breakdown Strength (50 c/s) at various temperatures

(a) Breakdown strength of feldspar,containing clinoenstatite bodies at various temperatures, on 1/16 in. thick test pieces.

Temperature in °C.	Breakdown strength volts/mil.
25	500
50	475
100	450
200	350
250	280

(b) Breakdown strength of improved clinoenstatite bodies (like Frequelex, Frequentite and Alsi-Mag. 196).

Temperature °C.	Breakdown strength volts/mil.
25	580
50	580
100	580
150	560
200	550
250	500

TABLE 7

Compressive Strengths

Porcelain (British High Tension Porcelain)	4,500—5,000 kg. per cm.²
	64,000—78,000 lb. per in.²
Frequentite "S"	6,000 kg. per cm.²
	85,000 lb. per in.²
Frequentite	9,000—9,500 kg. per cm.²
	128,000—135,000 lb. per in.²
Steatite	8,500—9,200 kg. per cm.²
	120,000—130,000 lb. per in.²
Frequelex (Plastic)	178,000 lb. per in.²
American Lava Corporation Ltd.	
Various Steatite and High Frequency Materials	75,000—85,000 lb. per in.²
German Publications (D.K.G.)	
Porcelain glazed, extruded	4,000—5,500 kg. per cm.²
Porcelain unglazed, extruded	4,000—4,500 "
Porcelain glazed, pressed	3,000—4,000 "
Porcelain unglazed, pressed	3,000—3,500 "
Steatite	8,500—9,500 "
" high frequency	9,000—10,000 "

To permit comparison with other insulating materials, the following data may be of interest :—

Polystyrol (Trolitul)	950 kg. per cm.²
Bakelite	1,200—2,000 kg. per cm.²
Bakelised paper	1,500 kg. per cm.²
Laminated paper sheet*	9—18 tons per sq.²
Polystyrene*	7 "
Aniline formaldehyde resins*	9 "

* "Plastes"—Plastics in Industry.

TABLE 10

Volume Resistivity at elevated Temperatures

Material	Te Values in °C.
Feldspar—containing clinoenstatite body	400
Various improved clinoenstatite bodies	800 to 1000 —
Cordierite bodies	600
Titania (High Permittivity) bodies	460

TABLE 11

Hardness

Material	Value in Mob's scale
Porcelain (unglazed)	7
Porcelain (glazed)	8.5 to 9
Clinoenstatite bodies	7.5
High permittivity (titania) bodies	8
Earthenware (unglazed)	6

TABLE 12

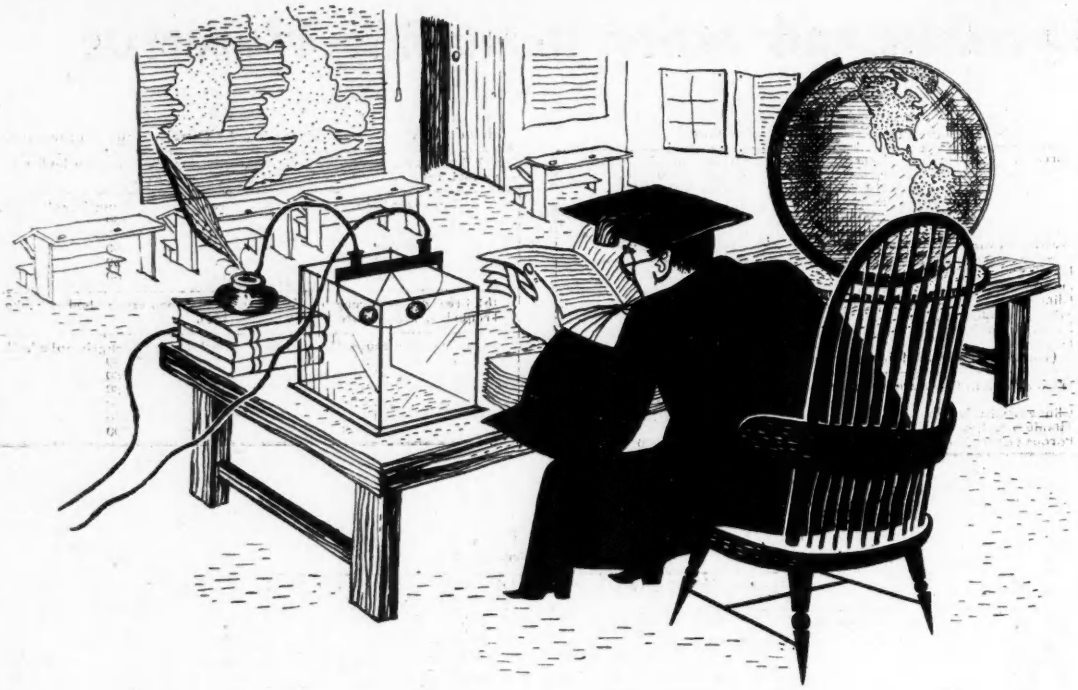
Thermal Expansion Coefficients

Material	Linear Coefficient of Thermal Expansion per °C × 10^{-6}
Porcelain bodies	4 to 5.5
Clinoenstatite bodies	6.9 to 7.7
Rutile (Titania) bodies	7.1 to 7.7
Cordierite bodies	1.3 to 2.5

TABLE 13

Thermal Conductivity

Material	Calories per sec. per cm. per °C.
Porcelain bodies	0.003 to 0.004
Clinoenstatite bodies	0.006
Rutile (Titania) bodies	0.008
Cordierite	0.003



10 out of 10, Mr. Canton!

John Canton was a London schoolteacher in the eighteenth century. Perhaps as a relief from giving daily instruction in the 3 R's, he himself turned scholar and learned all he could out of school hours about the then obscure subject of electricity. With few resources, he eventually made the first pith ball electrometer, and read a paper before the Royal Society on his method of producing artificial magnets. For this he was elected a Fellow and awarded the Copley medal.

We think that John Canton would have given Distrene (Regd.) 10 out of 10 for its outstanding insulating and electrical properties. The brief data below can be checked against the working samples; may we send them? Distrene is made in sheets, rods and tubes, and also as a moulding powder for injection machines. You get more mouldings per pound of Distrene than with any other plastic because of its low density and faster moulding rate.

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COMPRESSION STRENGTH	7 *tons per sq. in*
SPECIFIC GRAVITY	1·06
WATER ABSORPTION	*Nil*
COEFFICIENT OF LINEAR EXPANSION	·0001
SURFACE RESISTIVITY (24 hours in water)	3 × 10^6 *megohms.*
DIELECTRIC CONSTANT 60—10^6 CYCLES	2·60—2·70
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The Cathode-Coupled Double-Triode Stage

By EMRYS WILLIAMS, Ph.D., A.M.I.E.E.*

IN November 1941, S. E. Miller described in *Electronics* a highly stable and sensitive D.C. Amplifier, incorporating a precision Voltage Stabiliser.† In both the D.C. Amplifier and the Voltage Stabiliser there appeared a type of amplifier stage using a double-triode valve. The properties of this stage are so novel that they merit further description.

Fig. 1 shows the circuit of such a stage in its simplest form. The input voltage may be connected either between earth and grid 1 or between earth and grid 2, the other grid in each case being given a constant direct voltage. The output voltage is the p.d. across the load R in anode-circuit 1. With the input voltage in grid-circuit 1 there is the usual 180 degrees phase difference between input and output voltages, whereas with the input voltage in grid-circuit 2 there is zero phase difference between input and output voltages. The stage may be used as a D.C. amplifier, and also has an appreciable gain at supersonic frequencies. It may further be used as a Comparator, with an input voltage on each grid. The output voltage in this case is an amplified version of the difference between the two input voltages. A further valuable property of this stage is its ability to give automatic compensation for variations of cathode temperature—a very valuable property in a D.C. amplifier. Finally, in a D.C. amplifier several (but not an unlimited number) of such stages may be connected in cascade without the use of coupling batteries and without the necessity for an unduly large H.T. supply voltage. We shall consider this last property first

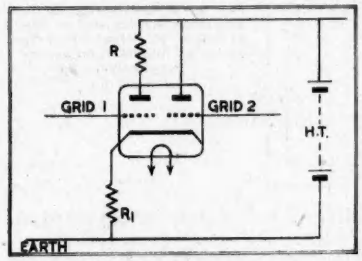

Fig. 1. Simple form of double-triode amplifier stage.

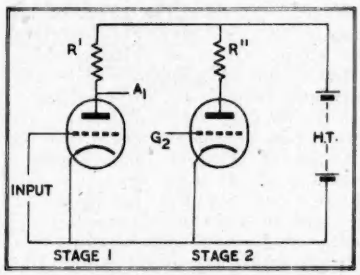

Fig. 2. In a multi-stage amplifier the potential variation of G_2 must follow that of A_1.

Use in Multi-stage D.C. Amplifier

In a multi-stage D.C. amplifier it is necessary to feed the output voltage of one stage into the grid-circuit of the next for further amplification, *i.e.*, the potential of point *G2* in Fig. 2 is required to vary exactly in accordance with variations of the potential of point *A1*. If the latter potential increases by 0.1 volt and remains at this higher value, we require the potential of *G2* to increase by 0.1 volt *and remain at this increased value.* This could not be achieved by Resistance-Capacitance coupling. The obvious course would seem to be direct connexion of *A1* to *G2*.

This direct method of coupling is usually rejected, however, because it makes it difficult to operate the second stage (and subsequent stages) with suitable values of steady grid and anode voltage. Instead, various methods of coupling have been used which involve the use of further batteries or D.C. supplies. For instance, a battery may be connected between *A1* and *G2*, of such polarity as to make the potential of *G2* always less than that of *A1* by a constant amount. So great are the disadvantages of using such batteries (*e.g.*, non-constancy of battery voltage, or alternatively the necessity of providing further stabilised D.C. supplies) that it is worth while to re-examine the objections to direct coupling and to see how the Cathode-Coupled Double-triode stage overcomes them.

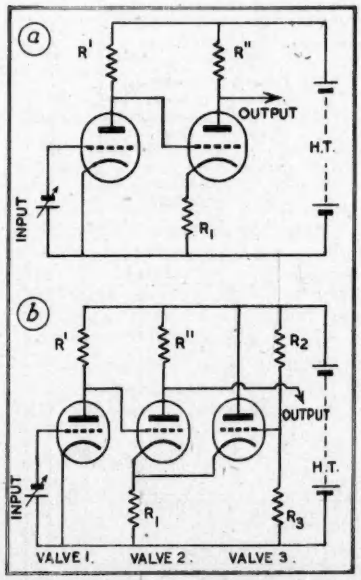

Fig. 3. (a) Raising the cathode potential by means of a resistor. (b) Maintaining the voltage across R_1 constant by means of a valve.

For stage 1 to amplify, its anode must be at a higher potential than its grid; hence direct connexion of the first anode, *A1*, to the grid, *G2*, of the second stage causes *G2* to be at a higher potential than *G1*, and so on throughout the amplifier. This leads to two difficulties, both of which (as we shall see) can be overcome without resorting to additional batteries.

The first difficulty is that of operating valve *2* with a suitable anode voltage. Suppose, for instance, that we require to operate each valve with a steady grid voltage of -1 and a steady anode voltage of 150; also that the H.T. voltage is 250, leaving a voltage of 100 to be dropped across the load of the first valve (*R'* in Fig. 2). This means that the anode of each valve is required to be 151 volts above its grid. But by direct coupling we have made *G2* at the same potential as *A1*, viz., only 100 volts below H.T. positive, and it is, therefore, not possible for *A2* to be 151 volts above this, unless the idea of a common H.T. supply be abandoned. The remedy is to operate the valves with steady anode voltages which are only a small fraction of the H.T. voltage. This may mean operating on the lower curved parts of the valve characteristics, but the effect of this is not serious when the range of variation of input voltage is small. As an example, let the anode voltage be 50 and the H.T. voltage 250; this leaves 200 volts to be dropped across *R'* and thus permits the use of a large load resistance. The potential of *A1* is now 50 volts above "earth" (*i.e.*, H.T. negative) and *G2* is at this same potential. If *A2* is 51 volts above *G2* (viz., 101 volts above earth) we still have (250 − 101) volts to be dropped across *R"*, the load of valve *2*. Even in the third stage (not

* University of Durham, Kings College, Newcastle.

† *See* also *Wireless World*, May, 1942.

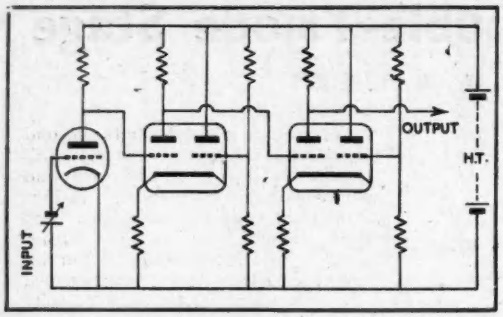

Fig. 4. A three-stage D.C. amplifier making use of the principle of voltage stabilisation by means of an auxiliary valve.

shown in Fig. 2) we should have G_3 and A_3 respectively at 101 and 152 volts above earth, leaving 98 volts to be dropped in the anode load of valve 3.

The second difficulty is that of operating valve 2 with a suitable grid voltage—and this is a more serious difficulty. We have just seen that the potential of G_2 is 50 volts above earth, whereas we require it to be 1 volt below cathode potential. Clearly the potential of the cathode must be raised to 51 volts above earth—and without recourse to batteries. This may be accomplished by the use of a bias resistor, R_1, as shown in Fig. 3 (a), though this would introduce negative feedback in the second stage, with a consequent serious reduction in amplification. If A.C. only were to be amplified, negative feedback could be prevented simply by the connexion of a suitable capacitance across R_1, for this would effectively short-circuit R_1, for A.C. and thus maintain the voltage across R_1 constant and independent of the input voltage of the stage. In a D.C. amplifier, however, it is not possible to maintain this voltage constant by means of a condenser. It is here that the Cathode-Coupled Double-triode comes to our aid.

The voltage across R_1 is here maintained constant by means of an auxiliary valve as shown in Fig. 3 (b). This valve (valve 3) is connected as a Cathode-follower *using R_1 as its cathode resistance*. R_1 thus becomes the common cathode resistance of valve 2 and valve 3. The grid voltage of valve 3 is maintained constant by means of the voltage-divider R_2 R_3 connected across the H.T. supply. The ratio $R_3/(R_2 + R_3)$ controls the voltage across R_1, as in a Cathode-follower. Valves 2 and 3 together constitute the stage which we have called the "Cathode-coupled Double-triode," and will be seen to correspond to the circuit of Fig. 1 with the input voltage connected in grid circuit 1 of that figure, grid 2 being maintained at a constant potential.

The manner in which valve 3 (Fig. 3(b)) contrives to maintain a constant voltage across R_1 may be explained as follows: The total grid voltage of valve 2 is made up of its "input voltage" (which in this case is the anode voltage of valve 1) and the RI drop across R_1. The former is a "grid-making-positive" voltage, and the latter a "grid-making-negative" voltage. Consider the effect of an increase of the former. This increases the anode current of valve 2 which increases the RI drop across R_1 (which is what we wish to keep constant). But the RI drop across R_1 is also part of the grid voltage of valve 3, and an increase of this RI drop therefore makes grid 3 more negative, and causes a decrease of the anode current of valve 3. This anode current, however, also flows through R_1, and so the RI drop across R_1 is restored almost to its original value.

Fig. 4 shows a three-stage D.C. amplifier making use of this principle.

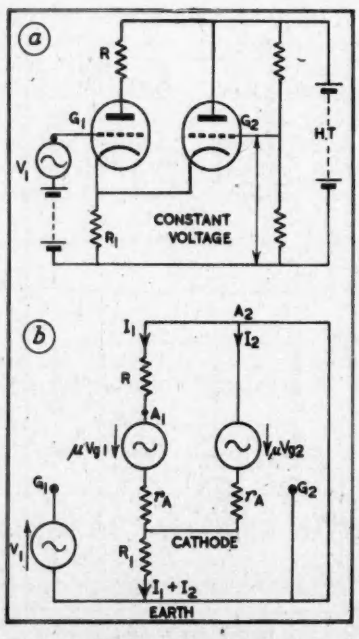

Fig. 5. (a) The actual circuit of Fig. 4 and (b), the equivalent circuit.

Gain of Stage, with Grid 1 as Input Grid

A more detailed examination of the performance of the stage may be made by adopting an equivalent circuit, in which a hypothetical generator of e.m.f. μV_g and internal resistance r_A takes the place of each valve. Fig. 5 (a) shows the actual circuit, and Fig. 5 (b) the equivalent circuit. In Fig. 5 (a) an alternating e.m.f. is used in series with the steady input voltage to denote the fact that the input voltage varies. Since the circuit incorporates no condensers or inductances, equal variations of input voltage will have the same effect whether they occur rapidly or slowly, and whether they are lasting changes or changes alternately in one direction and the other. We are therefore justified in selecting any one particular type of change for this investigation—and we choose a sine-wave alternating change (as indicated by V_1) because this enables us to treat the amplifier as an A.C. amplifier and to adopt the usual equivalent circuit.

Denoting the alternating components of the two anode currents by I_1 and I_2 as shown, we may apply Kirchhoff's Law to the closed circuit A_1-Cathode-Earth-A_2-A_1, giving the following equation:

$$\mu V_{g1} = (r_A + R + R_1)I_1 + R_1 I_2 \quad \ldots\ldots\ (1)$$

whereas for the closed circuit A_2-Cathode-Earth-A_2, we have

$$\mu V_{g2} = (r_A + R_1)\ I_2 + R_1 I_1 \quad \ldots\ (2)$$

Now V_{g1} and V_{g2} denote, respectively, the alternating components of the grid voltages of valves 1 and 2 (Fig. 5 (a)). The former is made up of V_1 and the alternating RI drop across R_1, *i.e.*,

$$V_{g1} = V_1 - R_1\ (I_1 + I_2)$$

The grid voltage of valve 2, however, varies only to the extent that the RI drop across R_1 varies, so that

$$V_{g2} = \quad - R_1\ (I_1 + I_2)$$

Substituting these expressions for V_{g1} and V_{g2} into equations (1) and (2), we have two equations from which we may solve I_1 and I_2. We wish to find the value of the voltage-amplification. This will be given by RI_1/V_1. We therefore solve for I_1 and multiply the answer by R/V_1. The result of these labours will be found to be

$$(\text{V.A}) = \frac{RI_1}{V_1} = \frac{\mu R}{r_A + R + \dfrac{r_A\,(R_1 + \mu R_1)}{r_A + R_1 + \mu R_1}}$$

Comparing this with the expression for the voltage-amplification of an ordinary amplifier stage (*viz*, $\mu R/(r_A + R)$), we see that there is here an additional term in the denominator. The presence of this term reduces the amplification. But this

term can never exceed r_A, so that in the worst case

$$(V.A.) = \mu R/(2r_A + R)$$

Thus the reduction of amplification is only slight, provided that the valve load R is several times as great as the valve impedance r_A.

Use of Grid 2 as Input Grid

If, in Fig. 1, grid *2* is used as the input grid, and grid *1* maintained at a constant voltage above earth, the circuit becomes as shown in Fig. 6(a). In this circuit we may regard the left-hand valve (valve *2* with the notation of Fig. 1) as a cathode-follower whose output voltage is the voltage across its cathode resistance R_1. This output voltage is coupled into the cathode circuit of the subsequent amplifier stage (valve *1*) and so varies the grid voltage of this stage. As described above, the use of a cathode resistance in this stage does not result in negative feedback.. When grid *1* is used as the input grid there is the usual 180 degrees phase-difference between input and output voltages; with grid *2* used as the input grid, however, as in Fig. 6, a rising input voltage causes a rise in the output voltage of the cathode-follower (*i.e.*, a rise in the voltage across R_1), which in turn *decreases* the right-hand grid voltage in Fig. 6. This decreases the right-hand anode current, and increases the potential of the right-hand anode. Thus an increase in input voltage causes an increase of output voltage, and there is zero phase-difference.

A more detailed examination can again be made by the use of the equivalent circuit, shown in Fig. 6(b). From this, and following the method given above, it can be shown that the voltage-amplification is given by

$$(V.A.) = RI_1/V_1 = \frac{-\mu R}{2r_A + R + \dfrac{r_A\,(r_A + R)}{R_1(1+\mu)}}$$

The minus sign simply indicates that in this case the phase relation between output and input voltages is the opposite of that in the previous case. The expression shows that, to avoid low amplification μR_1 must be large with respect to r_A. This is the same condition as applies to a cathode-follower stage—R_1 must be large with respect to $1/g_m$. If this condition is satisfied, the voltage-amplification is given by

$$(V.A.) = \frac{-\mu R}{2r_A + R}$$

As usual, this means that it is advisable to make the load resistance several times as great as the valve impedance.

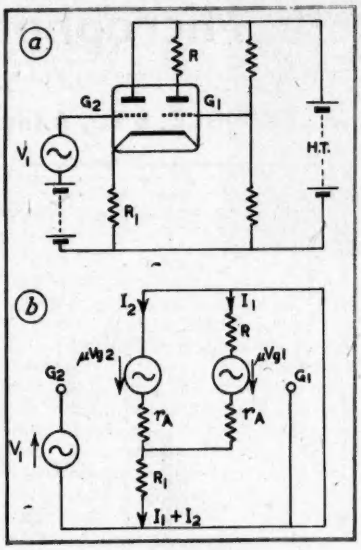

Fig. 6. (a) Circuit using Grid 2 as the input grid, and (b), its equivalent.

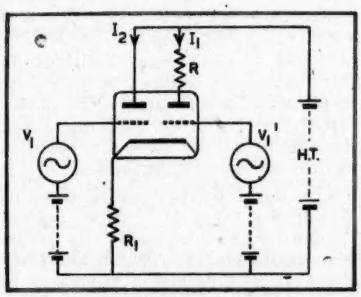

Fig. 7. Use of the double-triode stage as a differential amplifier.

Use as a Comparator

The stage may also be used as a Comparator, or Differential Amplifier. The two voltages to be compared (V_1 and V_1') are connected one in each grid circuit, as shown in Fig. 7. The output voltage due to V_1 is then 180 degrees out of phase with that due to V_1', and the total output voltage is therefore dependent upon the difference of V_1 and V_1'.

Analysing the circuit by means of an equivalent circuit, we find that the output voltage is given by

$$V_2 = RI_2 = \mu R\,\frac{(V_1' - V_1) + V_1'\dfrac{r_A}{R_1(1+\mu)}}{2r_A + R + \dfrac{r_A\,(r_A + R)}{R_1(1+\mu)}}$$

If R_1 is large compared to the reciprocal of the mutual conductance of the valve, making $R_1(1+\mu)$ large with respect to r_A, this approximates to the following:

$$V_2 = \frac{\mu(V_1' - V_1)R}{2r_A + R}$$

Thus the effect of applying V_1 in one grid circuit and V_1' in the other is the same as applying $(V_1' - V_1)$ in one grid circuit and maintaining the other grid at constant voltage above earth. The advantage of the circuit lies in the fact that when it is desired to amplify the difference between two voltages, *both of which have one side earthed*, it is not possible to connect them in series in the grid circuit of a single valve stage.

Compensation for Variation of Cathode Temperature

When the cathode temperature of a valve amplifier stage varies—and such stray variations are unavoidable—two things happen; first, the valve parameters vary and second, the D.C. anode current varies. Increase of cathode temperature would cause the valve impedance to decrease and the mutual conductance to increase, the amplification factor remaining relatively unchanged. If the load resistance is high compared to the valve impedance, the values of the expressions we have derived for the voltage-amplification will be but little affected by these changes. But the second effect, a change of D.C. anode current, is serious, for in a D.C. amplifier it would alter the output voltage of the first stage in just the same way as would a change of input voltage, and this change would be amplified by subsequent stages.

When the cathode temperature rises, and so increases the D.C. anode current, we may imagine the change of anode current as being produced by an "equivalent change of grid voltage." (Stewart E. Miller* considers an equivalent change of cathode potential.) If the two triodes of the Cathode-coupled Double-triode stage have a common cathode, the change of cathode temperature will be the same for the two triodes. Thus we may simulate the effect by the insertion of an equal voltage in each grid circuit. From what we have seen of the behaviour of the stage as a Comparator, it is clear that there will be only a very small effect on the output voltage. Apart from this advantage, there is nothing lost by using separate triodes for any of the purposes mentioned above.

* *Electronics*, November, 1941.

The Fürth Microphotometer

A description of an improved form of an Instrument which is entirely based on electronic principles

By R. W. PRINGLE, B.Sc., A.Inst.P. *

Introduction

IT is a matter of considerable importance in physical research to have an instrument which is capable of recording accurately the variations in transmissibility along a photographic plate. We have, therefore, seen the development of more than one highly successful microphotometer—for example, the Moll or Koch types. It may be remarked in passing that only recently there has been published an excellent bibliography of the somewhat extensive literature on the subject.[1]

A new type of microphotometer has been recently designed by R. Fürth[2,3] which will be of some interest to the readers of this journal as it is entirely based on electronic principles. It has three unique features which distinguish it from all other types of existing microphotometers :—

(1) The required curve is obtained on the screen of a cathode-ray oscillograph and thus a quick visual survey of the whole plate under examination is possible.

(2) Magnifications (200 or more) can be obtained which are much greater than with any other existing type.

(3) No elaborate gearing mechanism is incorporated.

One disadvantage of the new device was that the photometric curves obtained were rather thick and therefore lacking in detail. The present author has been able to improve the instrument in this respect[4] so that its resolving power is now comparable with that of other existing instruments. In the following a short account of the principles of the Fürth Microphotometer is given and a description of the recent improvements.

Description of the Instrument

The Y-Deflection

A schematic diagram of the complete instrument is given in Fig. (1). Lens L concentrates the light from a 12-volt, 6-watt lamp on to a slit S and a reduced image (1/12) of the slit is formed by the microscopic objective L_2 at the photographic plate P. The transmitted light is then condensed by the lens system L_3 on to the cathode of a gas-filled caesium-type photoelectric cell which requires a potential of about 100 volts for operation. Voltages developed across the load resistance R_8 are passed, after suitable amplification, to the Y deflector plates of a cathode-ray oscillograph (Mitcham Type GM 3152 in which the amplifier is incorporated). The photocell, battery, and the amplifier input leads must all be carefully shielded against external disturbances.

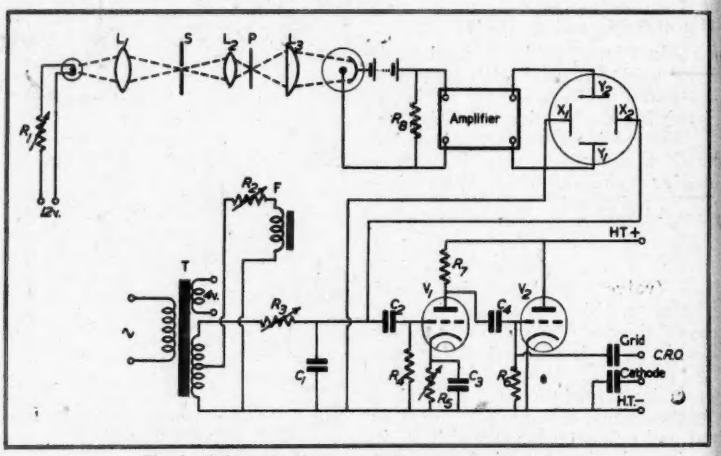

Fig. 1. Schematic diagram of the complete instrument.

$C_3 = 25\mu f.$ $C_4 = 0{\cdot}1\mu f.$ $R_1 = R_8 = 20$ ohms. $R_3 = 1{,}000$ ohms. $R_6 = 25{,}000$ ohms. $R_7 = 250{,}000$ ohms. $R_9 = 1{\cdot}1$ Meg. For other values see text.

The small plate P which is to be examined is fixed in a holder carried by one end of a magnetically polarised tuning fork (natural frequency about 50 c/sec.) which is supported in a horizontal position and the arrangement is such that oscillations of the fork cause the plate to move in a vertical direction with its plane normal to the axis of the optical system. The tuning fork is maintained magnetically and the current for the fork coil F is supplied by a 12-volt winding on the mains transformer T. The amplitude of the forced vibrations of the fork can be controlled by the rheostat R_2, but it should be noticed that owing to the finite inertia of the moving parts there will be a phase difference between this vibration and the controlling voltage.

The X-Deflection

The 50-volt terminals of the transformer T are connected across a phase-shifting device which consists of a condenser C_1 (.01μF) and a variable resistance R_3 (maximum value .25MΩ) in series. The X plates of the oscillograph, being placed in parallel with this condenser, can now be supplied with a sinoidal time base which has the same frequency and *phase* as the mechanical oscillation of the plate P.

Suppose now the plate to contain a photograph of a spectrum where the lines are parallel to the slit S. The vibration of the plate across the light beam being equivalent to a vibration of the slit image along the spectrum over a range equal to twice the amplitude of vibration of the fork, it will be seen that the X deflection of the oscillograph is an enlarged copy of this motion of the slit image.

Now the Y deflection is proportional to the intensity of illumination of the photocell and, since this is proportional to the transparency on the plate of the particular line just passing the slit image, the spot of the oscillograph traces the transparency curve automatically. Different parts of this curve can be brought successively into the field of observation by moving the vibrating mechanism vertically with the aid of a micrometer adjustment.

The Improved Record

The curve obtained in this way is really the superposition of two traces writing in opposite directions on the screen of the cathode-ray oscillograph, and corresponding to the two directions of the vibrational motion of the plate through the slit image, and hence fluctuations in the mains frequency or voltage can cause slight relative displacements of the two

* Physics Department, University of Edinburgh.

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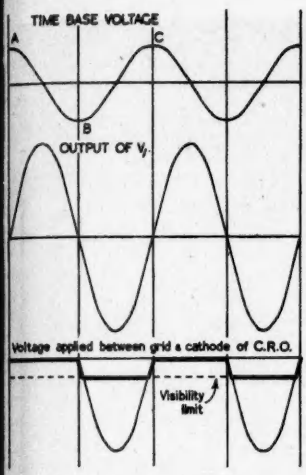


Fig. 2. (left.) Diagram to illustrate blanking of one trace.

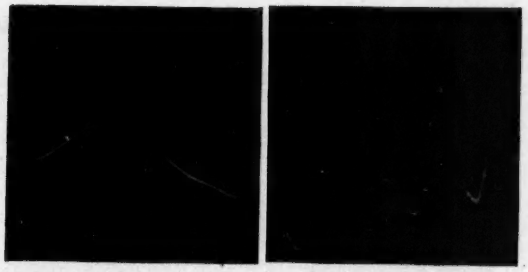


Fig. 3. Two records obtained with the apparatus : A (left) is a magnified portion of B (right). *(By courtesy of " Nature ").*

traces which result either in a thick curve or a splitting up in two curves.

A periodic " square-wave " voltage is now applied between grid and cathode of the oscillograph and this controls the brightness of the fluorescent spot in such a way as to make only one trace visible. To do this the time base voltage is applied across resistance R_4 (5,000Ω) and condenser C_3 (.02μF) in series, and the result is to produce across R_4 an alternating voltage of about 1 volt and removed more than 88° in phase from the time-base voltage. Triode valve V_1 functions as an amplifier for this voltage and V_2, which is unbiased and has a high- grid resistance, clips off the positive peaks of the output from V_2 due to grid current flow (*see* Fig. 2). The dotted line indicates that potential corresponding to the limit of visibility, and the thick line therefore shows approximately the fluctuations in brightness of the fluorescent spot. Comparison of curves (1) and (2) shows that in the interval AB we have a bright spot and in the interval BC nothing is visible. So a single trace has been obtained.

Examples

In Fig. 3 are shown two photographic records taken with a Ross 9-in. lens using Ilford Rapid Process Panchromatic Plates with an exposure time of 3 seconds.

Both records relate to the density distribution in a photograph of the arc spectrum of copper in the neighbourhood of 3,440 A°, taken with an ordinary glass spectrograph. Record B (with original magnification of 30) covers a range of 15 A° approximately. Record A is of the central hump in record B; it corresponds to an original magnification of 200 and covers a range of 2.2 A°, and a distance of 0.24 mm. on the spectrum photograph. On the oscillograph screen a distance of 1 mm. corresponded to 0.3 A° in the case B and to 0.045A° in the case A.

The two records not only give some indication of the improved performance of the instrument, but serve to illustrate how the magnification can be altered at will to study more closely any desired portion of the photometric curve.

This article would be incomplete without my thanks to Prof. Born and Dr. Fürth of the Mathematical Physics Department of this University for their encouragement in this work.

1 Ronnebeck, H. R. *J. Sci. Instr.* **20** (1943), p. 159.
2 Fürth, R. *Nature*, **149** (1942), p. 730.
3 Fürth, R. *Proc. Phys. Soc.*, London, **55** (1943), p. 34.
4 Pringle, R. W., *Nature*. **153** (1944) p. 81.

An Electronic Insulation Tester

THE B.T.-H.-Forrest Test Set is the first commercial electronic apparatus for testing insulation at high voltages and is based on a design already described by J. S. Forrest.*

Testing sets previously available incorporate a microammeter for the measurement of leakage current, and, in some cases, the test voltage is generated by a D.C. machine.

In the electronic test set, not only is the D.C. test voltage produced by a valve, but the leakage current is measured by a cathode-ray (" magic eye ") indicator. This is more robust and less expensive than a microammeter of equivalent sensitivity.

The set is energised from any low voltage A.C. supply. By means of a step-up transformer and an H.T. rectifier, known values of D.C. voltage are made available. A known variable resistor is inserted in the circuit under test and the voltage across this resistor is applied to the control electrodes of the tuning indicator. From the characteristic of the indicator the current through the resistor can be deduced. The calibration chart provided gives the relation between the shadow angle and the insulation resistance in megohms.

The D.C. voltage is variable in steps of 1, 2, 3, 4, and 5 kV., and at the highest figure resistances up to 20,000 MΩ can be measured.

It is desirable that the relative humidity be checked at the time of testing, since a humidity in excess of 65 per cent. may produce variations in the results.

The overall dimensions of the tester are 19 in. by 14 in. by 8¼ in. deep and the total weight is 60 lb.

Further particulars can be obtained from the British Thomson-Houston Co., Rugby.

The Forrest Insulation Tester ready for use.

* J.I.E.E., 89, Pt. II, p. 288.

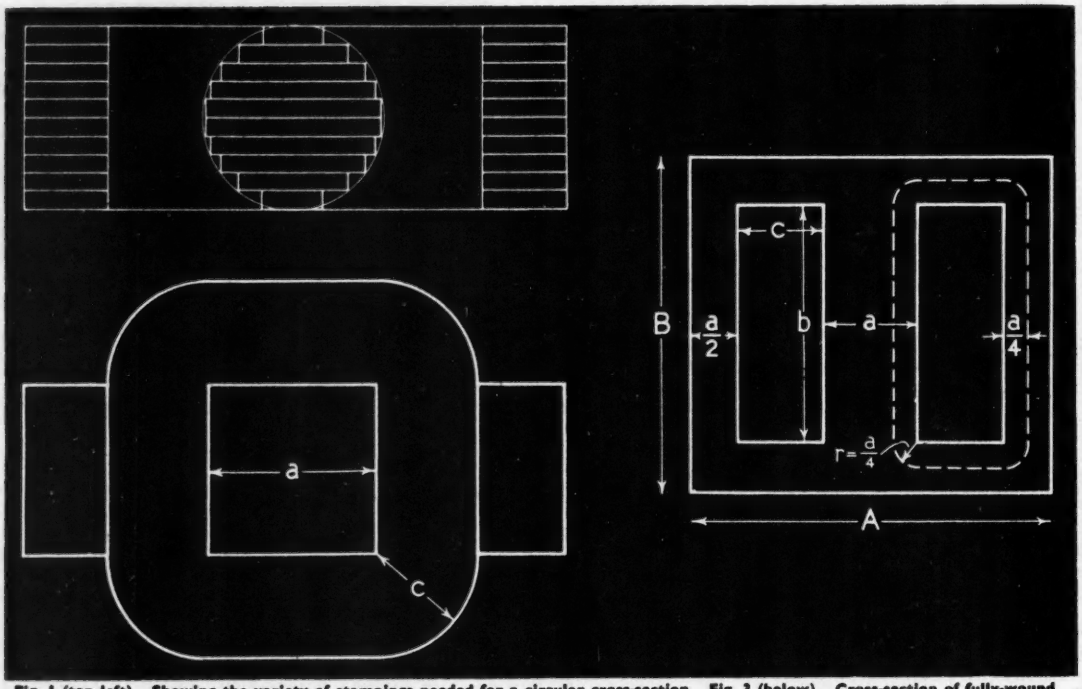


Fig. 1 (top left). Showing the variety of stampings needed for a circular cross-section. Fig. 3 (below). Cross-section of fully-wound transformer. Fig. 2 (right). Dimensions of stamping showing mean iron path dotted.

The Design of Stampings for Low Frequency Transformers

By R. MAWSON, B.Sc.

Summary.

After obtaining an expression by which the relative merits of stamping shapes may be compared, this formula is used in the following ways :

(a) To determine the optimum core area and position of the core.
(b) To determine the optimum stamping when one dimension is fixed.
(c) To determine the optimum shape of the stamping for a given area.

A second formula is used to determine the shape of the stamping giving the maximum inductance for a given wire size.

Introduction

The losses in any transformer can be grouped under four headings, two of which are winding losses and core losses. In this paper the core losses have not been considered as they are essentially properties of the magnetic material of which the stampings are made and are in practice, relatively small at low frequencies. The winding losses are made up of three separate factors, the loss due to the ohmic resistance of the winding, the loss due to skin effect and that due to proximity effect. Of these three, the last two are negligible at low frequencies. Loss due to leakage inductance and self capacity are the other two sources of power loss and these are much more dependent on the method and arrangement of the windings than on the shape of the stampings.

Thus the main source of power loss for low frequency transformers is the ohmic resistance of the winding. It is, therefore, proposed to obtain a formula expressing the inductance in terms of the copper resistance.

Formula Derivation

$$N=\frac{\beta A_c}{a_c}, \text{ where}$$

N = Total number of turns.
β Space Factor : Area copper section/Total area.
A_c = Total winding space.
a_c = Cross sectional area of wire.

$$R_c=\frac{Nl_c\rho_c}{a_c}, \text{ where}$$

R_c = Copper resistance.
l_c = Length of mean turn.
ρ_c = Specific resistance of copper.

$$L=\frac{\phi N}{I}=\frac{N}{I}=\mu HA_1, \text{ where}$$

L = Inductance.
ϕ = Total flux.
I = Current flowing.
A_1 = Cross-sectional area of iron.
H = Magnetising force (r.m.s.).

$$H=\frac{4\pi NI}{10l_1}, \text{ where}$$

l_1 = Length of mean iron path.

$$L=\frac{4\pi NI}{10l_1}\cdot\frac{\mu A_1 N}{I}\times 10^{-8}$$

$$=\frac{4\pi A_1\mu N^2}{10l_1}10^{-8}$$

$$\frac{L}{R_e}=\frac{4\pi\mu A_1}{10 l_1}\left(\beta\frac{A_e}{a_e}\right)^2\frac{a_e^2}{l_e\rho_e\beta A_e}\,10^{-8}$$

$$=\frac{4\pi\mu\beta}{10^8\rho_e}\cdot\frac{A_1A_e}{l_1l_e}$$

This formula contains the factor A_1A_e/l_1l_e which is independent of everything but the shape of the stamping. Henceforth this factor will be called K.

K is clearly a factor which can be used to express the relative merits of the shape of the stampings. The dimensions of K are length squared so if all the dimensions of a stamping are doubled K will be quadrupled. This agrees completely with practice in that the bigger the stampings the less the transformer loss becomes.

Optimum Core Size for given Overall Dimension of Stamping

For the factor K to be large it is clear from the formula that the area of iron has to be a maximum and the length of copper a minimum. This necessitates the core being circular, but as this is extremely difficult in practice, needing a large number of graded stampings (*see* Fig. 1) a square cross section has been chosen.

The side limbs have been chosen half the width of the centre limb, which gives the same flux density throughout the iron.

An existing stamping is shown in Fig. 2, the values for A being 2.0 in. and B 2.2 in.

$A_1=a^2$ $A_e=bc$ where $b=B-a$ and $c=A-2a$

$l_e=4a+\pi c$ $\qquad l_1=2(b+c)+\frac{\pi}{2}a$

$$K=\frac{a^2bc}{(4a+\pi c)(2(b+c)+\frac{\pi}{2}a)}$$

For maximum K $\partial K/\partial a=0$.

Let $\frac{f}{K}=\frac{1}{K}\frac{\partial K}{\partial a}$. As K is not zero and $\frac{\partial K}{\partial a}=0$ for maximum K, then the value of 'a' to satisfy $f=0$ is the optimum value for the given external dimensions.

Expanding and collecting terms.

$$f=\frac{a^4-8.59a^3+25.42a^2-30.28a+11.53}{2a(a-2.2)(a-1)(a-2.76)(a-1.9)}$$

For all practical solutions, $a<1$ the denominator cannot become infinite, so all the inflexion points for the function K are given by the solution of

$a^4-8.59a^3+25.42a^2-30.28a+11.53=0$

This equation has one or three positive roots and solving by any of the accepted methods gives $a=.71$.

The original stamping has dimensions

$a=.5$ $B=2.2$ $A=2.0$

giving a value for K of 1.14×10^{-2}. The new stamping has dimensions of

$a=.71$ $B=2.2$ $A=2.0$

giving a value for K of 1.28×10^{-2}.

Changing the external dimensions of the stamping to A=2.2 and B=2.0, and solving for optimum core width gives the values below:—

$a=.78$ $K=1.28\times10^{-2}$.

From this it is clear there is an optimum value for the core width for any given external dimension.

Optimum Shape when one Dimension only is Fixed

Using the same symbols as previously

$$K=\frac{a^2bc}{(4a+\pi c)(2(b+c)+\frac{\pi}{2}a)}$$

We can write without any loss of generality, $a+b=1$; this unit is any arbitrary unit of length. The maximum value for K using this will give the optimum ratio of 'a' and 'c', and hence b.

$$K=\frac{a^2c(1-a)}{(4a+\pi c)(2c+(\frac{\pi}{2}-2)a+2)}$$

As K is now a function of two independent variables the maximum is given by $\frac{\partial K}{\partial a}=\frac{\partial K}{\partial c}=0$.

$$\frac{1}{K}\frac{\partial K}{\partial a}=\frac{2}{a}-\frac{1}{1-a}-\frac{4}{4a+\pi c}-\frac{\frac{\pi}{2}-2}{2c+2+a\left(\frac{\pi}{2}-2\right)}$$

$$\frac{1}{K}\frac{\partial K}{\partial c}=\frac{1}{c}-\frac{\pi}{4a+\pi c}-\frac{2}{2c+2+a\left(\frac{\pi}{2}-2\right)}$$

$\frac{\partial K}{\partial c}=0$ when $\frac{4a}{c(4a+\pi c)}=\frac{2}{2c+2+a\left(\frac{\pi}{2}-2\right)}$

$$\pi c^2=4a+2a^2\left(\frac{\pi}{2}-2\right)$$

$$c^2=\frac{4}{\pi}a+\frac{2}{\pi}a^2\left(\frac{\pi}{2}-2\right)$$

substituting in

$$\frac{2}{a}-\frac{1}{1-a}-\frac{4}{4a+\pi c}-\frac{\pi/2-2}{2c+2+a(\frac{1}{2}\pi-2)}$$

for 'c' and solving gives a = .61, b = .39, c = .82

The value of K for this stamping is .0070.

This shape is the optimum shape if one side is given, but it does not necessarily follow it is the optimum shape for a given area of stamping.

Optimum Shape for a Given Area of Stamping

Taking the overall area of the stamping as 2 and using the same formula as before we have the two equations

$$K=\frac{a^2bc}{(4a+\pi c)(2(b+c)+\frac{1}{2}\pi a)}$$

$$1=(a+b)(a+c)$$

Values for A and B were chosen such that A B equals 2 and the optimum value for 'a' was found, the results are listed below:—

A	B	Maximum $K\times10^3$	Corresponding value of 'a'
1.414	1.414	approx. 5.9	approx. .4
1.6	1.25	6.63	.49
1.7	1.1725	6.72	.515
1.8	1.11	6.73	.53
1.9	1.0526	6.80	.54
2.0	1.0	6.37	.55

To complete this work the values for K are compared and also the value K is obtained which is the value of K for stampings of equal area (4.4 sq. in.).

	$K\times10^{-2}$	$K^2\times10^{-2}$
Sample stamping	1.14	1.14
Sample stamping with optimum 'a'	1.28	1.28
Sample stamping with optimum 'a' at right angles	1.28	1.28
Optimum stamping with one dimension fixed	.70	1.07
Optimum stamping with area fixed	.68	1.50

Stamping Shape for Maximum Inductance

Another desirable shape is based on the maximum inductance for a given wire size.

Using the same symbols as before we get

$$L = 4\pi\mu N^2 \frac{A_i}{l_i}$$

$$N = \beta \frac{A_e}{a_c}$$

$$L = \frac{4\pi\mu\beta^2}{a_c^2} \cdot \frac{A_i A_e^2}{l_i}$$

Thus the factor $\alpha = \frac{A_i A_e^2}{l_i}$ is an indication of the maximum inductance, obtainable with a given wire size.

Designing as previously on the basis of a given area we have

$$(a+c(a+b)=1 \quad \alpha = \frac{a^2b^2c^2}{2(b+c)+\frac{1}{2}\pi a}$$

Using Lagrange's method of undetermined multipliers the maximum for α is given by the solution of the following equations. λ is a constant.

$$\frac{2\alpha}{a} - \frac{\pi/2}{2(b+c)+\frac{1}{2}\pi a} + \lambda(a+c+b+c)=0 \quad \ldots (1)$$

$$\frac{2\alpha}{b} - \frac{2}{2(b+c)+\frac{1}{2}\pi a} + \lambda(a+c)=0 \quad \ldots (2)$$

$$\frac{2\alpha}{c} - \frac{2}{2(b+c)+\frac{1}{2}\pi a} + \lambda(a+b)=0 \quad \ldots (3)$$

eliminating $\alpha - \lambda$ from equations (2) and (3)

$$\left(\frac{2}{b} - \frac{2}{2(b+c)+\frac{1}{2}\pi a}\right)(a+b) = \left(\frac{2}{c} - \frac{2}{2(b+c)+\frac{1}{2}\pi a}\right)(a+c)$$

$$1+\frac{a}{b} = 1+\frac{a}{c}\,\frac{1}{2(b+c)+\frac{1}{2}\pi a}\,(a+c-a-b)$$

$$\frac{a(c-b)}{bc} = \frac{c-b}{2(b+\frac{1}{2}\pi a}$$

$$\frac{a}{bc} = \frac{1}{2(b+c)+\frac{1}{2}\pi a} \quad \text{or } b=c$$

As a, b and c are all positive in the case of a practical solution, the only answer is b = c.

This gives the external dimensions of the stamping as A = 2 and B = 1. Using these values and solving for a gives a = .361, in which case $\alpha = 6.96 \times 10^{-6}$.

MAY MEETINGS

Institution of Electrical Engineers

London Section

The annual general meeting for Corporate Members and Associates only will be held at the Institution on May 11, at 5.30 p.m.

The meeting will be followed by a paper on "Modern Submarine Cable Telephony and the Use of Submerged Repeaters," by R. J. Halsey, B.Sc., at 6.15 p.m.

Measurements Section

On May 19, at 5.30 p.m., a paper will be read by L. Hartshorn, D.Sc., on "Foundations of Electrical Measurements."

Transmission Section

On May 10, at 5.30 p.m., a paper on "Remote Switching by Superimposed Currents" will be read by J. L. Carr, B.Sc.

Wireless Section

To commemorate the Silver Jubilee of the above Section a Commemoration Meeting and Dinner have been arranged for May 3. The meeting will be held at 5.15 p.m., and preceded by a reception and tea at 4.30 p.m. Owing to limited accommodation tickets for the dinner will be restricted to members of the Section, and a few guests.

Students Section

The annual general meeting will be held on May 15, at 7 p.m.

Cambridge and District Wireless Group

On May 1, at 5.30 p.m., at the Cambridgeshire Technical School, a discussion on "Training for the Radio Industry" will be opened by C. R. Stoner, B.Sc., and R. W. Wilson.

A paper will be read on May 11, at the University Engineering Department on "The Contribution of Cambridge to Radio Engineering," by Dr. E. B. Moullin.

Brit. I.R.E.

London Section

The next meeting will be held at the Institute of Structural Engineers, 11 Upper Belgrave Street, London, S.W.1, at 6.30 p.m., on May 25, when a paper on "The Electron Gun of the C.R. Tube—Limitations in its Performance," will be read by Dr. H. Moss, of Messrs. A. C. Cossor, Ltd.

Midland Section

On May 17, at 6.30 p.m., at The University of Birmingham (Lati Theatre) Edmund Street, Birmingham, a paper will be given by Emry Williams, Ph.D. (Member) on "Re laxation Oscillators and Trigge Circuits."

Institute of Physics

Electronics Group

On Thursday, May 4, in the Rooms of the Royal Society. Burlington House, London, W.1, a paper will be read on "The Electrostatic Generator, its Development and Prospects," by L. G. Grimmett, of the Radio Therapeutic Unit, Hammersmith Hospital.

Industrial Radiology Group

At a joint meeting in Manchester with the Manchester and District Branch of the Institute, a paper on "Filters and Intensifying Screens—Their Applications in Light Alloy Radiography," will be read by C. T. Snushall. The meeting will be held in the Physics Department of the University, at 2.30 p.m., on Saturday, May 20.

British Kinematograph Society

A symposium on "Better Projection," will be held at the Gaumont-British Theatre, Film House, Wardour Street, on May 10, at 6 p.m. A specially produced film will be shown to illustrate the points made.

Institution of Electronics

A meeting of the N.-W. Branch will be held at the Reynolds Hall, College of Technology, Manchester, on Friday, May 19, at 7 p.m.

The subject of the lecture will be "Selenium Photo-Cells," by G. M. Tomlin and C. Wontner (Salford Electrical Instruments, Ltd.).

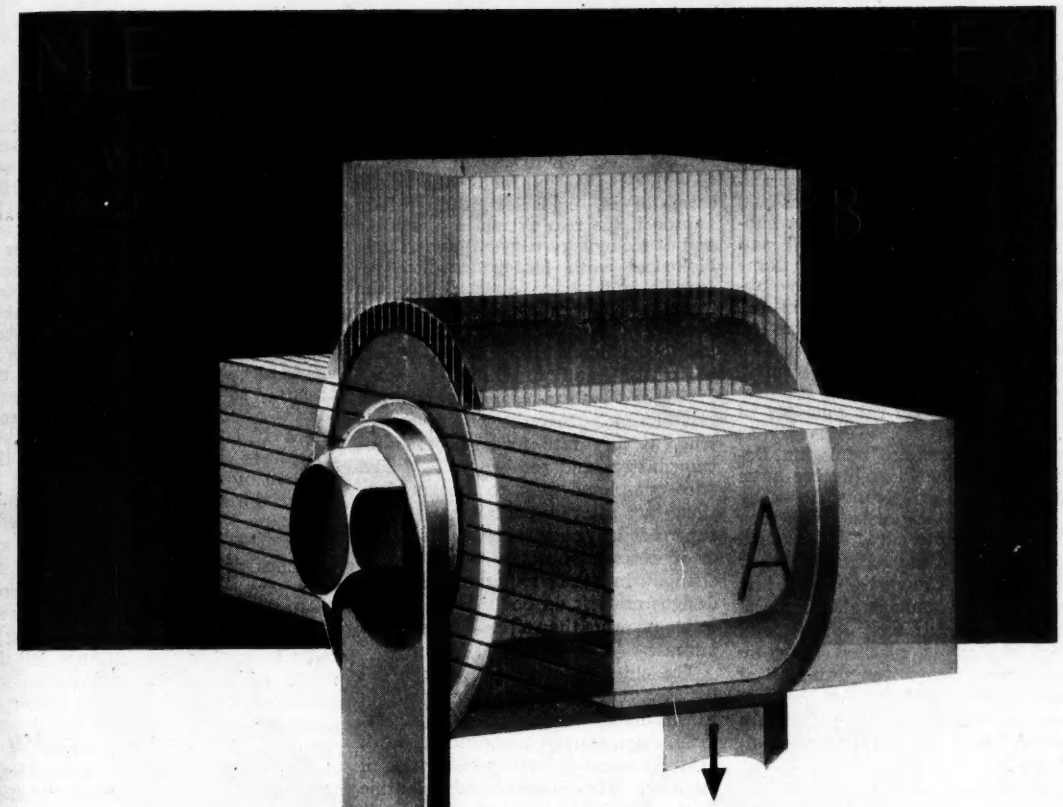
Tickets on application to Mr. L. F. Berry, 14 Heywood Ave., Austerlands, Oldham.

Bradford Electronics Society

On May 24, at 7 p.m., at the Bradford Technical College, a lecture will be given by P. Nagy, on "The Signal Convertor."

Electronic Music Group

The next meeting of the above group will be held on May 13, at 2.30 p.m., at the Northern Polytechnic Institute, Holloway Road, N.7, when a paper on "The Case for New Tone Colours," will be read by Mr. P. T. Hobson (Messrs. Boosey and Hawkes).



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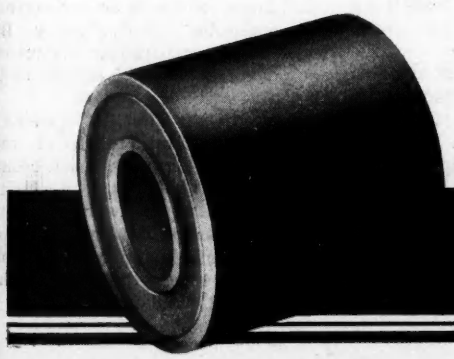
These values, thanks to the Metalastik rubber-to-metal weld, are additional to the resistance of rubber-in-compression common to all rubber-annulus bushes.



METALASTIK

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A Biologist Looks at Radio

By E. W. SIMON, B.A.

IN the early days of the war, many students at the Universities were allowed to continue with "peacetime" studies, only to find themselves switched over to very different subjects when they had graduated and took on some form of war-work. Some curious combinations must have resulted from this; I am one of the biologists who are now working on radio. The greatest difficulties that I found in learning radio from scratch, came at the beginning, when I had to become familiar with the concepts of A.C. theory and radio. Terms such as Potential, Impedance, Modulation, Detection and Integration, involve more than a mere definition can state—they are concepts in the sense that they involve a definite idea. Once such concepts have been acquired, they seem simple and indeed obvious, just as in learning a language at first the grammar seems extremely difficult, and correct syntax is reached only by constant attention to the grammatical points, though later on it becomes almost automatic as one becomes familiar with it—one acquires a "feeling" for it.

Research work in radio seems to me to involve relatively little that can properly be called scientific, most of it being of a technological nature. Scientific research is concerned with the fundamental problems; examples of these in radio are rather scattered—the study of thermionic emission and fluorescent screens, the piezo-electric effect in certain crystals, and the transmission of wireless waves and design of aerial systems. Here, as in studies such as analytical physiology and biochemistry, one attempts to interpret observations and experimental results in terms of phenomena of a lower order—usually the structure and behaviour of cells in the case of physiology, and the movements of electrons in radio. The aim of such work is the discovery and analysis of new phenomena, at present unknown or poorly understood. In technological work the aim is something more concrete than this, such as the design of a circuit to fulfill certain specified functions. Technology is based on the knowledge provided by science, and proceeds, as it were, to erect a superstructure of inventions from this basis.

Now science and technology are inter-related in a number of ways, and in many studies such as metallurgy it is hard to say where the one ends and the other begins, but biology and radio seem to be fields of study which approach the two extremes of science and of technology respectively. Little biological work (except medical research, and that directed to the increase and improvement of food production) is done with any other immediate object than the "unveiling of truth," and a discovery once made and substantiated stands the test of time. In radio, the reverse is true, at any rate for the design of transmitters and receivers. A design once completed may go into production, but after a period it is either superseded by something that is better or it becomes obsolete because of a change in the requirements. Old designs are left on one side and often retain no more than a passing historical interest.

The chief differences I have found between biology and radio relate back to this distinction between science and technology, though experimental work in radio seems to have peculiarities of its own. The fundamental scientific facts and theories on which radio is based, should enable one to design a circuit to fulfill any given function, with comparative ease. This, however, is frequently not possible, because full and complete data for the performance of circuit components are often not available.

At audio frequencies, design data are so complete that reference to the appropriate tables will give all the information needed to construct an almost perfect job. But to design a high-frequency circuit which will perform exactly what is wanted as soon as the parts are assembled, may be a very arduous or even an impossible task. It is quicker to try something that looks likely, and one determines what looks likely in part by the application of a sort of qualitative theoretical approach, but largely by intuitive judgment based on experience. One builds up, then, a probable circuit, and finds more likely than not that it will not work. First, one measures voltages and currents, and then listens to the circuit if it has an audio output, or perhaps one looks to see how the circuit is behaving by means of a cathode-ray oscillograph. This is an instrument that is very nearly neutral to the circuit, and can show how it is behaving without at the same time altering the behaviour. In this way one soon learns what circuit elements will control the behaviour of a circuit, and in what manner. So one automatically tends to make certain components of critical value variable, instead of fixed in value; their tolerance is so close that they must be adjusted *in situ* after assembling the circuit. It may also be found necessary to alter the values of components which had been fixed at what was considered the correct value. The process of altering such values, of trying this and trying that, is called "frigging"—a peculiarly descriptive term. By frigging about, one approaches closer to the end in view, be it a pure sine wave, a distortion-free amplifier, or a short-wave receiver. One of the characteristics of frigging in radio is that one can at once tell the result of a particular experimental gambit by seeing it on a meter or oscillograph, or by hearing it in the 'phones. So one may arrive at a simple technique of "try it and see." This must be contrasted with the more usual need in scientific work to design a rigid experimental technique to study the effects of the inter-action of the variable factors. There will usually be a considerable time lag between deciding what is to be tried out, and arriving at a result. This may be the time taken by a chemical or biological process to end—often a matter of hours or days, it may be the time needed to draw a graph, or the time spent in repeating the experiment often enough to obtain a statistically significant result. In much of the work connected with receiver design, however, one can actually see, or hear, the results of putting in a resistor or changing a condenser as one performs the operation. The rapidity with which one can experiment on electronic equipment seems to be unique to this class of study.

Such are my first impressions of radio. In general, much of radio seems to me to deal with easier, because more explicit problems than much of biology, but for this same reason I find it the less satisfying of the two. This is a personal opinion, and I should be interested to hear the views of others who have had similar experiences.

Callender

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All over the World

Frequency Compensating Attenuators

by G. S. Light, B.A.Sc. (Toronto).

This article explains the nature and extent of the subjective frequency distortion caused by the reproduction of a radio programme at a loudness level different from the original, and considers means of compensating for this effect.

THE Weber-Fechner Law states that "the minimum change in stimulus necessary to produce a perceptible change in response is proportional to the stimulus already existing." This applies to the frequency and intensity of sounds perceived by the human ear. Thus, one note which is 12.2 per cent. higher in frequency than another is recognised to be a major tone higher irrespective of the absolute frequencies involved. Similarly with regard to intensities, a change of 12.2 per cent. in r.m.s. air pressure is perceived as the same definite amount of change (1 db) irrespective of the absolute pressures involved. But the apparent amount of change varies with frequency, and the characteristics of the average ear in this respect are expressed in the well-known "loudness contours" of Fletcher and Munson. These show that the effect of reproducing a programme at a lower level than the original is apparently to weaken the bass, and to a less extent the treble; hence the thin sound of music on many receivers at a low volume control setting. When reproducing at a higher level than the original, the bass appears unnaturally accentuated, particularly on male speech.

These effects can be removed by frequency compensating circuits associated with the volume control but at this point two assumptions are necessary which can be modified later if required :—

1. That the listener wants the frequencies that he hears to have the same relative amplitudes that they would if he were listening in the broadcasting studio.

2. That the compensation required to achieve this is in respect of the subjective distortion only, *i.e.* that the complete chain from microphone to loudspeaker has a flat frequency characteristic. This is nearly true of modern high fidelity transmission and reception. In the present state of the art the weakest link would seem to be the loudspeaker.

Now for the attenuator design. Let us arbitrarily take the average level at the microphone to be 70 phons, and the average level at the listener's ears at his normal distance from the loudspeaker to be 70 phons also, when the volume control is at maximum. Then when he reduces the level of reproduction by 10 phons, the compensation required will be given by the difference between the 70- and 60-phon contours; similarly for other degrees of attenuation. The required compensation thus obtained is nearly all in the bass, and in round figures amounts to 2 db per octave below 400 c/s. at -10 db, 4 db per octave below 500 c/s. at —20 db, and 6 db per octave below 600 c/s. at —30 db. Substantially the same results are obtained when the original level is taken as 60 or 80 phons instead of 70. The 1 or 2 db discrepancies in the treble can be ignored.

All that is wanted therefore is an attenuator giving a bass boost which increases with the attenuation in the specified manner. There are several circuits which have this property. The tapped volume control shown at (1) is a compromise since the compensation is exact at one setting only and at others is insufficient. This method also requires a special control. The choke method shown at (2) errs in the opposite direction. If L=200 henries and the potentiometer is 250,000 ohms, the compensation is almost exact

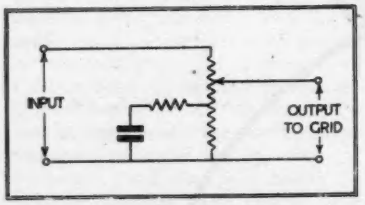


Fig. 1. Attenuator giving bass boost.

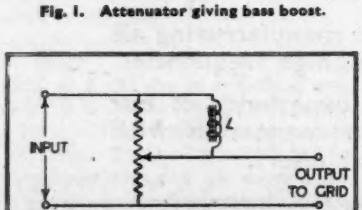


Fig. 2. Bass boost using choke compensator.

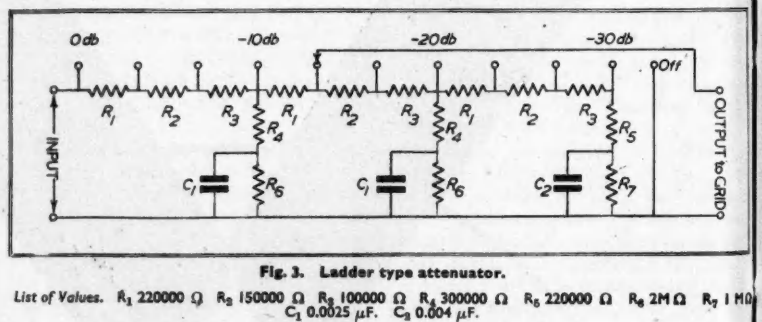


Fig. 3. Ladder type attenuator.

List of Values. R_1 220000 Ω R_2 150000 Ω R_3 100000 Ω R_4 300000 Ω R_5 220000 Ω R_6 2M Ω R_7 1 MΩ C_1 0.0025 μF. C_2 0.004 μF.

Table of Characteristics (db. boost)

Frequency	—10 db		—20 db.		—30 db.	
	Required	Obtained	Required	Obtained	Required	Obtained
25	7	6.5	14	14	22	22.5
40	6	6.5	13	12.5	21	20.5
65	5	5.5	11	11	17.5	17.5
100	4	4.3	9	8.5	14	14.5
150	3	3	6	5.7	10.5	11
250	2	1.5	3.5	3	7	7.5
400	0.5	0.5	1.5	1.5	3	4
650	0	0	0	0.5	0	2
1000	0	0	0	0	0	0.5

at —10 db, but slightly too much at —5 db and insufficient to an increasing extent below —10db. With the same inductance and a 500,000 ohm potentiometer the compensation is almost exact at —20 db but excessive above and insufficient below this setting. A practical objection is the tendency of this choke to pick up hum. The writer has tried other combinations of reactances with potentiometers and has concluded that the required results cannot be obtained using an ordinary untapped control.

We are thus led to the use of a tap switch and with this there are a number of solutions to the problem. The ladder-type circuit shown at (3) approximates very closely to the desired performance at all attenuations, the table shows the actual (measured) results compared with those required. 30 db total attenuation is ample (*e.g.* it represents the range from 10 W to 10 mW) while the 3 1/3 db steps are quite convenient. From the practical point of view, no hard-to-get parts are necessary, only one Yaxley switch deck and standard-value resistors and condensers are required. The preceding load resistance should not exceed 100,000 ohms. The use of such an attenuator will ensure that the reproduction will appear to have the same frequency characteristics at all levels.

Reactances are necessarily used in these circuits, and the load line for the preceding valve becomes elliptical in consequence. This should be borne in mind as it follows that the permissible voltage swing for a given amount of harmonic distortion is reduced. For this reason tone correction circuits are preferably used only in low-level stages.

Separate manual tone control is still desirable for the following reasons :—

1. There may be frequency distortion in the transmitter (especially on recorded programmes).

2. The programme level may not be equal to the maximum output level of the receiver. No frequency compensation is used by the B.B.C. for different programme levels.

3. The listener's ears may not have average characteristics. Audiometer tests show that variations of as much as 10 db are quite usual. (Similarly slight astigmatism is usual in persons with normal sight).

4. Unless the receiver AVC is exceptionally efficient the differing volume levels obtained from different stations will upset the frequency compensation arrangements.

5. In any case the listener's taste and mood should be provided for.

Terminological Inexactitudes

In a letter to the *Journal of Scientific Instruments*,* L. V. Chilton of Messrs. Ilford, Ltd., draws attention to the confusion in the terms relating to photography and radiography. His remarks are of particular interest in view of the growing use of the word "microgram" in electron microscope practice.

He says :—

"There still seems to be some uncertainty as to the difference between photomicrography and microphotography."

This is all the more unfortunate as it leads to a like confusion in the records produced by agencies other than light, *e.g.*, X-rays and electrons.

The leading authorities in this country and U.S.A have now long recognised† the following distinction :—

Microphotography: The production of very small photographs (generally of large objects).

Photomicrography: The production of much enlarged photographs of very small objects.

Applying the same principle to photographs obtained with other radiation we have :—

Ultra-violet Micrography: Micrography with ultra-violet light.

Electron Micrography.—Direct micrography with electron beams.

X-ray Micrography (*Radio-micrography* (deprecated): Micrography with X-rays, a process in which a contact radiograph of a thin specimen is made on a fine-grain film and is subsequently viewed with the aid of a microscope.

Radiograms, and the Like

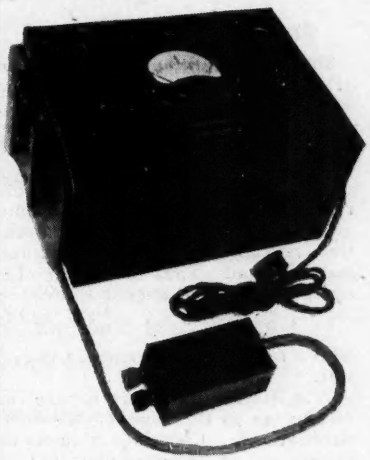
The word "radiogram" is commonly used with three different meanings, one of which is :—

Radiogram: An X-ray shadow photograph (*Roentgenogram; Skiagram; Radiograph*).

The writer calls attention particularly to this example as illustrating a convention which is well known but inconsistently applied, *viz.*, the reservation of the suffix *-scope* for an optical instrument without photographic recording, *-graph* for an optical instrument with recording, and *-gram* for the record.

This convention is in regular use in some fields, *e.g.*, spectroscope, spectrograph, and spectrogram. Can we not reasonably hope for its extension to others, such as microscope, micrograph, and microgram?

* *J.S.I.*, Vol. 21, No. 2, Feb. 1934.
† *Pop. Sci. Rev.*, 6, p. 54, (1867).



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CORRESPONDENCE

Preferred Resistor Values

DEAR SIR,—In the leading article of your April issue you refer to the standardisation of resistance values. From the Erie advertisement in the same copy and other sources, we gather that this standardisation has been brought about by dividing the range between 10^n and 10^{n+1} ohms into 12 parts so that the ratios of consecutive resistance values are approximately equal. Thus the values between 10 ohms and 100 ohms, are

10, 12, 15, 18, 22, 27, 33, 47, 56, 68, 82, 100

with a ratio varying between 1.18 and 1.25.

Was it really necessary to take the number 12 as the basis of this standardisation? Choosing 10 intervals instead of 12 corresponding to the values,

10, 12.5, 16, 20, 25, 31.6, 40, 50, 63, 80, 100,

would result in the following advantages.

(1) The series of values corresponds to the decibel system with which most communication engineers are already familiar.
(2) The series contains round values such as 20, 25, and 50 which were used before the "Standardisation."
(3) To every resistance value there is twice the value and half the value in the series.
(4) The ratios of consecutive resistances differ less from each other (Variation 1.25-1.28).
(5) Every resistance can be characterised by two figures, the first indicating the "subseries" in which the value occurs (0 for 1-8 ohms, 1 for 10-80 ohms, 2 for 100-800 ohms, etc.) and the second indicating the position within this subseries (0 for 1, 10, 100 . . . , 1 for 1.25, 12.5, 125 . . ., 2 for 1.6, 16, 160 . . ., etc.). Written with a decimal point, these two numbers are very nearly equal to the logarithm of the resistance value. For example, 4.3 represents a resistance of 20,000 ohms, this value being No. 3 in subseries No. 4, and log 20,000 equals 4.3. The same scheme could also be used for a simplified system of colour coding requiring only two dots for the whole range from 1 ohm (0.0) to 8,000 megohms (9.9).

Yours faithfully,

Per pro. BOWEN INSTRUMENT CO., LTD.,
W. BOWEN, Gov. Director.

We should be interested to have readers' opinions on this matter.—Ed.

EDITORIAL NOTE: *A copy of Mr. Bowen's letter was sent by him to the B.S.I., and their position is made clear in the following reply, which is reproduced by permission:—*

The Bowen Instrument Co.

. . . This Institution fully appreciates the advantages of using the Perfected Series of numbers as a basis for ranges of sizes and values. Wherever practicable this principle is adopted, but in many cases established practice precludes the evolution of a logical range to displace an existing range.

In the case of radio resistors, standardisation is, at the present time, in the hands of the Inter-Service (Communications) Components Committee, and although the specifications prepared by that Committee are published by the Institution, the actual drafting of the specification is in the hands of the Committee.

Your letter has therefore been forwarded to them for consideration.

—Yours truly,

J. F. STANLEY
Electrical Section).

The Electronic Baby

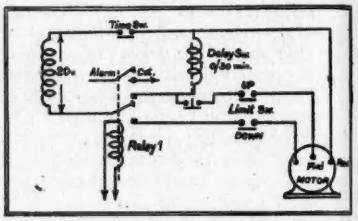
SIR,—The initial surprise caused by the article, "An Electronic Baby Alarm" abated somewhat when investigation revealed that a new species of mammal was not contemplated, and the discovery that electronic appliances were being designed for the well-being and comfort of the young, in addition to those being designed for the investigation of the discomforts of the old, inspired the writer to attempt some contribution of his own.

Since the offspring of the electronic engineer is invariably of high intelligence, his (or her) audio output is naturally conserved in order that the indication of the need of premier importance, i.e., food, is of maximum effort. A mere alarm, therefore, is not the complete solution, and the attached diagrams will show how some attempt has been made to improve the position.

The sequence of operations is obvious:

(1) The baby cries.
(2) Relay 1 closes, energising the motor, which thus lowers the bottle.
(3) "Down" limit switch operates (opening.).
(4) The baby seizes the bottle and is solenced.*
(5) Relay 1 falls out, closing back contacts, and energising delay switch.
(6) Delay switch closes, after the preset delay, energising the motor, which raises the feeding bottle.
(7) "Up" limit switch operates.

The baby, as previously indicated, being of high intelligence, soon discovered that a prolonged yell had similar properties to the magic "Sesame! Sesame!" producing at any time the offering of a juicy milk-filled teat, and this necessitated some safety precautions.



A time switch was therefore fitted as shown. This is set to cover periods of up to one hour, at the time suggested by the nursing home, and needs no further attention, apart from rewinding, except to cope with summer-time and double summer-time changes.

Some constructional details may be of use:—The A.C. motor is an ordinary "tuning" motor. The cable drum is made narrow so that the winding speed in the vicinity of the baby, is very much lower than that at the opposite end of its travel, thus ensuring a gentle approach to, and retreat from the baby. The bottle is attached to the cable by some 12 inches of rubber strand, thus, upon expiry of the feeding time as determined by the delay switch, should the removal of the bottle be contested by the baby, the resultant "tug-of-war" so exhausts him/her that the ultimate release of the bottle is immediately followed by a sound and lengthy sleep.

Although I do not expect to attain everlasting fame from this contribution to the science of electronics, I hope to achieve the undying gratitude of a large body of female war-workers.

—Yours sincerely,

B. SHAW.

P.S.—The bottle is, of course, held in an electrically heated, thermostatically controlled fitting, while awaiting the baby's demands—a salvage crystal oven fills the bill admirably. The amplifier is identical with that of the article which inspired the project.

* Useful portmanteau word, coined by the printer, for solaced and silenced.—*Ed.*

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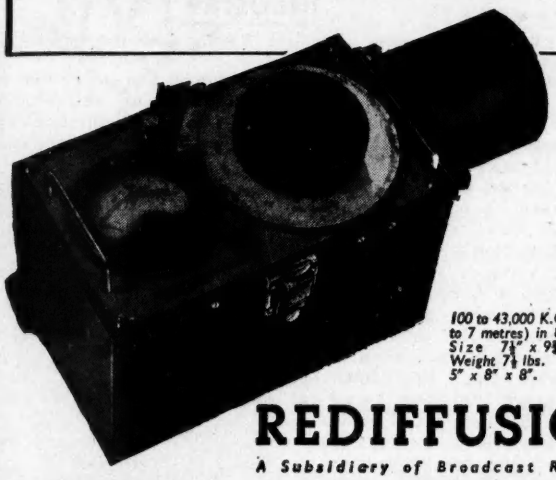

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ABSTRACTS OF ELECTRONIC LITERATURE

MEASUREMENT

A Fast and Sensitive Bolometer and Galvanometer System for an Infra-Red Spectrometer

(E. B. Baker and C. D. Robb)

This bolometer and associated equipment, designed for use with a high-speed recording infra-red spectrophotometer, respond in two-tenths of a second to 6×10^{-8} watt of radiation from a slit. Amplification of the Brownian limit of the Moll microgalvanometer in the presence of difficult vibrations is achieved by mounting the galvanometer, photocells, and pre-amplifier on a novel support employing a large compression spring. The bolometer and amplifying system described were developed for use with a *f*4 rocksalt infra-red spectrophotometer. In order to show the spectrum on the screen of a long-persistence (one minute) oscilloscope, unusually rapid response was desired, even at the expense of some sensitivity.

—*Rev. Sci. Inst.* Vol. 14 (1943, p. 356.

Electrodynamic Slit Unit for an Infra Red Double Monochromator

(E. B. Baker and C. D. Robb)

Electrical control of slit width by means of the unit described permits continuous adjustment as the wave-length is changed so that constant energy output of the monochromator may be achieved. As a result, per cent. absorption is measured directly and the slits are always set for optimum resolving power. An additional feature is curvable slits which are preset for any wavelength desired. The unit is supplied from an amplifier for automatic output control.

—*Rev. Sci. Inst.* Vol. 14 (1943), p. 359.

Temperature Coefficient of Capacitance

(W. Shick)

The paper discusses the requirements for the measurement of temperature coefficient of capacitance of small radio condensers, and analyses possible errors with a view to defining conditions for the achievement of a certain accuracy. Various electrical and thermal methods are then reviewed as a preliminary to the description of an apparatus which was specially designed for the purpose.

—*Wireless Engineer.* Vol. 21 (1944), p. 65.

THEORY

The Electric Spark Discharge in Different Gases

(T. E. Allibone, J. M. Meek)

The theory of breakdown in a nearly uniform field due to a constant or l.f. alternating voltage is developed. Calibration curves are shown for an ionised and an unionised gap between 13 mm. diameter spheres, errors being attributed to inadequate irradiation. Breakdown due to impulse voltages is discussed; little difference is noted between breakdown voltage of a gap under impulse voltages and that under sustained voltages if gap irradiation is identical in each case. Breakdown of the diverging field due to a constant or l.f. alternating voltage is also discussed; in this case, corona is observed to precede breakdown, in contradistinction to the breakdown of the uniform field. The impulse breakdown of the diverging field always occurs for long gaps in air at a value in excess of the l.f. breakdown value.

—*J.Sci.Inst. February,* 1944, pp. 21-27.*

Ultrashort Electromagnetic Waves v. Radiation

(A. Alford)

The first part of this article presented a method for calculating the radiation fields of radiators with a known current distribution. The method now presented is for the calculation of the field in space on the basis of known field distribution in the vicinity of the radiator. The advantages of this method over the Kirchhoff - Huygens procedure formerly used for the calculations of radiation from wave guides and electromagnetic horns is stressed.

—*El. Engg.*, Aug., 1943, p. 338.*

Valve Amplification Factor

(H. Herne)

A new treatment of the electrostatic field of a triode is outlined, and it is shown to be valid for values of the grid wire diameter from zero to two-thirds of the grid pitch. A formula for the amplification factor of a planar triode is deduced, and it is shown to be the product of two factors, the first dependent on the grid geometry alone and the second on the anode to grid plane spacing: a graph is given for the rapid evaluation of the amplification factor of specific geometries. The extension of the method to other geometries and to multi-grid valves is indicated.

—*Wireless Engineer. Vol.* 21 (1944), p. 59.

INDUSTRY

Radiographic Inspection—I

(L. Mullins)

It is common knowledge that radiography is becoming well established in industry as a reliable non-destructive method for the examination of welds, and this article reviews some of its fundamental theoretical aspects, proceeding then to give a comprehensive account of its practical applications to modern industry and a description of typical X-ray equipment. The three types of sensitised photographic materials used for recording the X-ray image and the action of the different types of screens are explained. Brief mention is also made of other accessories and of the processing of the film.—

—*Welding.* Mar., 1944, p. 135.*

The Cyclotron—I

(M. S. Livingston)

The cyclotron is fast becoming an indispensable tool for applied science and industry and this article describes the instrument, its principles, operation and application to industry. The radio-activities and neutron radiations are being put to use in industry and medicine on an ever increasing scale and it is considered that the time is near when the use of the cyclotron as a production unit may outweigh its further scientific usefulness. This paper evaluates available information which may aid in determining the most economical sizes and designs for large-scale application.

—*J.App.Phys.* January, 1944, pp. 2-19.*

High Frequency Heating of Laminated Materials

(A. E. L. Jervis.)

Problems relating to the high frequency heating of laminated materials are discussed. It is claimed that the method of placing the high frequency electrodes parallel to the edges of the veneers needs considerably less power than that of placing them parallel to the faces. Four typical electrode arrangements are shown. Data are presented giving the effect of moisture variation on the characteristics of laminated wood. The article concludes with a discussion on the advantages of h.f. heating and a typical calculation in which the capacity equivalent resistance of a given board is estimated and the approximate voltage of the set calculated.

—*El. Times.* 12/1/1943, p. 624.*

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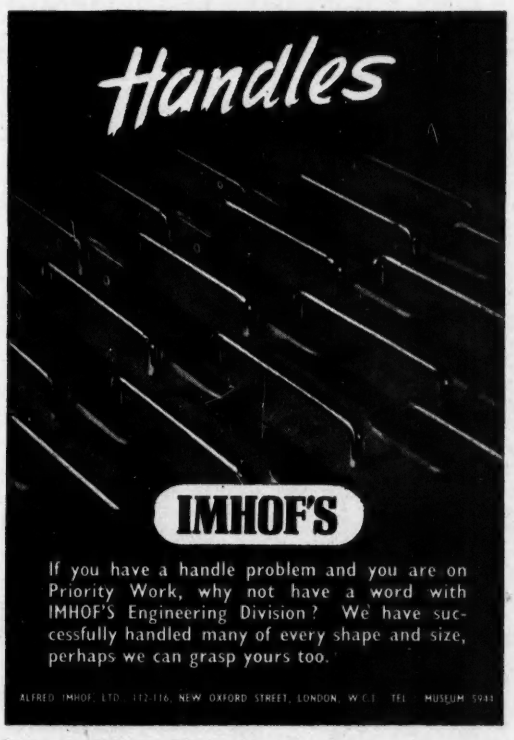

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BOOK REVIEWS

The Radio Amateur's Handbook

(Twenty-first edition, 1944) by the Headquarters Staff of the American Radio Relay League. 664 pp., 1125 illustrations, 125 charts and tables. Price $1.50.

This new 1944 edition differs from previous editions mainly in the considerable expansion and revision of the "theory" part of the book—the chapters on fundamental principles and design. Chapter Two on Electrical and Radio Fundamentals, for example, has been doubled in length. Chapter Three on Vacuum Tubes, has been enlarged about 60 per cent. Explanations of certain principles have been amplified where practical teaching experience showed this to be desirable, and discussions of additional topics useful as grounding for students of all branches of modern radio technique have been included.

The "construction and data" section of the book closely follows the familiar pattern of recent editions, with the exception that one new chapter has been added—that on Carrier-Current Communication.

Always an outstanding feature of the Handbook, the classified vacuum-tube data tables have been revised to include some fifty new tubes on which data was released during the year, and continue to be the most complete listing of the kind available anywhere. A new added convenience is a supplementary cross-index by type numbers to facilitate locating tubes whose classifications are not known.

Basic Radio

by J. B. Hoag. 358 pp. 38 figs. (Chapman & Hall, 21s. net).

This book is designed for the student with a limited background in physics and mathematics, and the author strives to keep to the happy medium between over-simplification and mathematical explanations.

There are 38 chapters, giving an average of 10 pages per chapter, so it will be seen that the author has to "go some" to compress the essentials into the space allocated, especially as he includes photo-cells, C.R. tubes, Transmitters, U.H.F., and microwaves.

Necessarily, this leads to somewhat cursory treatment in some cases, but the parts of the book dealing with purely radio matters are well illustrated and arranged. A chapter on special circuits deals with pulse generation, electronic counting and electronic switching, and that on microwaves gives a fairly complete description of the klystron and wave guides. There is a list of references at the end of this chapter which could with advantage be extended to cover the subject matter of each of the chapters, and, finally, there is a list of test questions at the end of the book.

Books reviewed on this page or advertised in this Journal, can be obtained from

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If not in stock, they will be obtained from the Publishers when available

Books Received.

Elements of Radio: Marcus (*Allen & Unwin*)
Handbook of Engineering Plastics: D. W. Brown (*Newnes*)
Optical Workshop Principles: Dévé (*Hilger Ltd.*)
The Complete Morse Instructor: Tait (*Pitman & Son*)
Guide to Cathode Ray Tube Patterns: Bly (*Chapman & Hall*)

Cherchez la Femme

The trite saying above has no connection with this advertisement except to catch the attention of you hard boiled business men. We want only to remind you that Parmeko of Leicester concentrate on the design and production of efficient TRANSFORMERS and any job we turn out (either 'special' or in quantity) is just as good as a transformer can be and certainly better than most. What were you saying . . . something about cost? Well we are not expensive, that is a fact, but on the other hand we ought to warn you that we are not cheap because a Parmeko transformer is made up to a standard not down to a price! How about letting us work out a price for you to judge for yourself - just send it on because we would like to know you anyway and we think it would benefit you to know us -

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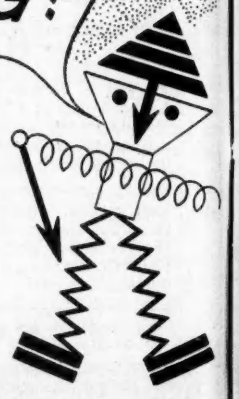

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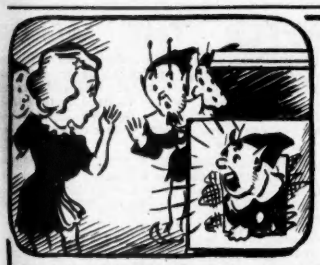

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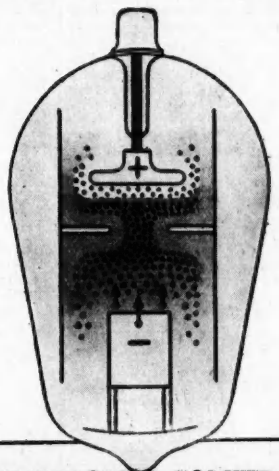

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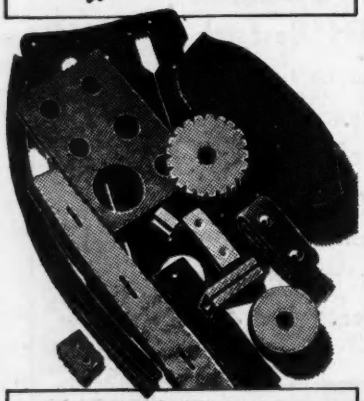

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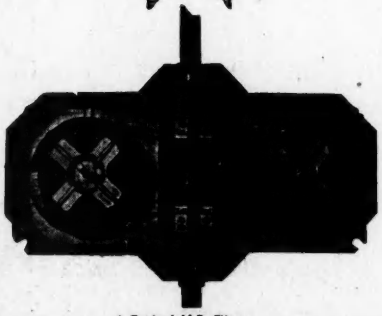

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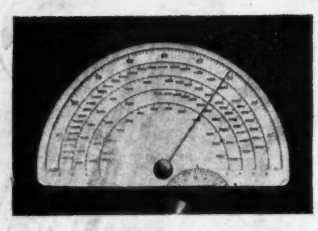

DIAL CALIBRATION

The above photograph gives a clear idea of the manner in which the dial is marked. Four coils have direct calibration and the remainder are referred by graphs to the outer scale. The small Logging Scale is gear driven from the Drive Mechanism and, therefore, positive in action. By quick reference to the outer scale and the pointer reading thereon, and the reading of the logging scale, it is possible to return to any given point at any time quickly and accurately; further, any number of stations working on fixed wavelengths can be logged and returned to for operational purposes.

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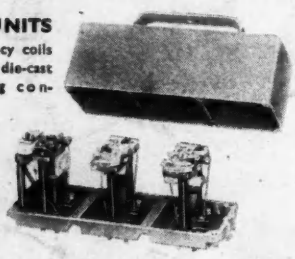
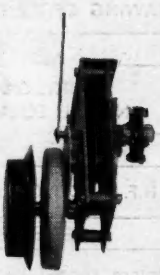


Tuning ranges :

Range	Kc/s.	Range	Kc/s.
A	22,000—31,000	F	600— 1,250
B	9,000—22,000	G	300— 600
C	4,500— 9,000	H	150— 300
D	2,100— 4,500	I	90— 150
E	1,250— 2,100	J	40— 90

TUNING DIAL DRIVE MECHANISM



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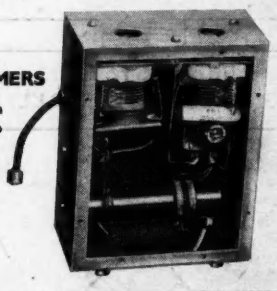

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